SYSAPP-98/21

Final Report

EFFECT OF CHEMICAL MECHANISM UNCERTAINTY ON AIRSHED MODEL RESULTS: PHASE II

Systems Applications International, Inc.

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Contents

SUMMARY

The standard Carbon Bond-IV (CB4) chemical mechanism is used in the regulatory version of the Urban Airshed Model (UAM) that the U.S. EPA maintains on its internet bulletin board system. During Phase I of this study two alternative forms of the standard CB4 mechanism were developed and tested against smog chamber data: these alternative forms are characterized by either a high or a low radical-flux version of the same chemistry. The results of Phase I were reported by Whitten and Killus (1998). During Phase II of this study the alternative versions of the chemistry were implemented into the regulatory UAM and the various combinations of standard and alternate chemistries were used to simulate control strategy scenarios. The results reported here are intended to demonstrate a potential range of uncertainty in airshed control strategies due to uncertainties in the chemistry.

As part of Phase I, box model tests indicated that the alternative versions should give different control strategy implications, especially when the scenario involves changing the emissions ratio of volatile organic compound (VOC) to nitrogen oxides (NOx). Therefore, the control scenarios chosen for the UAM simulations performed in Phase II involved changing the emissions ratio; this was accomplished by reducing either VOC or NOx by 50 percent compared to the base case emissions for two 1987 episodes in the South Coast Air Basin (SoCAB). The box model tests further indicated that the strongest impacts on controls might be seen for regions where the base VOC-to-NOx ratios are low, which is another reason to select the SoCAB for UAM testing.

The results from the UAM simulations show many (but minor) variations throughout the SoCAB. There appears to be no consistent pattern for the two alternative representations of the CB4 mechanism. As expected they each tend to provide similar base case results, which implies that overall UAM model performance would not be significantly different. However, it was unexpected to find that even though control strategy simulations varied between the three versions of chemistry, the high and low-flux alternates did not produce consistent impacts compared to the standard chemistry. For example, for the 25 June, 1987, episode-day at the Norcor monitoring site a 50 percent VOC control showed the greatest percent ozone reduction using the high flux chemistry, but at the Perris site high flux chemistry gave the least impact from VOC control. Another type of example was seen for local areas that tend to show simulated ozone increases from NOx reductions: for 25 June, 1987, at the Rubidoux monitoring site, the high flux chemistry was the only version to show any ozone reduction (from NOx control), but at a site near Azusa, high flux chemistry produced the greatest ozone increase from NOx reduction. Apparently, consistent patterns predicted by box models can be obscured in grid models that have more complex emissions variations in time and space. Also in grid models, transport time to specific sites is fixed by the meteorology, but ozone formation timing can be affected by radical flux, so that an impact predicted by a box model might occur at a different site in a grid model.

INTRODUCTION

Kinetic mechanisms used for simulating photochemical smog formation in regulatory models such as the Urban Airshed Model (UAM) are evaluated using data from smog chamber experiments. Before being published in the *Journal of Geophysical Research* the Carbon Bond mechanism version four (CB4) was tested against 170 experiments involving three different smog chambers. The U.S. Environmental Protection Agency, who sponsored the development of the CB4, also carefully reviewed the protocols used to evaluate this mechanism before recommending its use in regulatory applications of the UAM.

The California Air Resources Board has designed the present study to develop alternative versions of the CB4 that, on one hand, fall within the range of published mechanistic uncertainties and still meet some measure of acceptable performance for simulating a smog chamber database, but, on the other hand, provide different estimate of control strategy effectiveness when used in the UAM. These different control strategy estimates will then define a measure of the bounds of uncertainty that might exist in regulatory applications of the UAM, due solely to uncertainties in the CB4 itself.

In the Phase I final report the development and validation of the alternative mechanisms was described. These alternative versions of the CB4 are called the high and low radical flux versions. These alternative mechanisms were constructed by increasing (for high flux, decreasing for low flux) all radical sources and sinks by 30 percent. These net radical sources and sinks affect only 16 reactions in the CB4 mechanism (See Table 1). Such changes tend to produce similar steady-state levels of the various free radicals important to the overall chemistry, but the "flux" of radicals through the system of chain reactions is much higher or lower than in the standard CB4. Similar levels of radical concentration were believed necessary to provide acceptable simulations of the smog chamber data. A fundamentally important criteria for simulating smog chamber data has always been the decay rates of key VOC species that depend strongly on the concentration of radicals, especially the hydroxyl radical [OH]). Ironically, the performance of VOC decay is not often reported, but a mechanism that produced good ozone simulations from poor performance on VOC decay would have little value in regulatory applications.

In addition to testing the alternative mechanisms against smog chamber data, box model simulations were performed in Phase I to estimate the potential for changes in control strategy predictions compared to the standard CB4 chemical mechanism. These box model tests indicated that the alternative versions <u>should</u> give different control strategy implications, especially when the scenario involves changing the emissions ratio of volatile organic compound (VOC) to nitrogen oxides (NOx). Such results were considered reasonable because many radical sources tend to come from the organics (e.g., formaldehyde photolysis), while a key radical sink comes from the NOx (i.e., the reaction of OH with NO_2). Exceptions, however, would be first that ozone itself is also an important radical source (through the ozone photolysis to O^1D followed by reaction with water) and second that radical-radical sinks are important when NOx concentrations become low.

RESULTS

CONTROL STRATEGY IMPLICATIONS USING A GRID MODEL

Base Year Simulations

The South Coast Air Basin was chosen as the modeling domain. Two 1987 SCAQS episodes (June and August) were used. All inputs were obtained from the ARB ftp site. The June episode is a three-day simulation and the August episode is a two and half-day simulation.

Standard UAM/CB4 simulations (Base87): Figure 1 shows the results for the June episode. The simulated maximum hourly ozone concentrations are 154 ppb on June 23, 139 ppb on June 24, and 151 on June 25. The results for the August episode are shown in Figure 2. The maximum hourly ozone concentrations are 128 ppb on August 27, and 161 ppb on August 28.

High flux UAM/CB4 simulations (Base87): Figure 3 shows the results for the June episode. The maximum hourly ozone concentrations are 150 ppb on June 23, 147 ppb on June 24, and 146 on June 25. The results for the August episode are shown in Figure 4. The maximum hourly ozone concentrations are 126 ppb on August 27 and 162 ppb on August 28.

Low flux UAM/CB4 simulations (Base87): Figure 5 shows the results for the June episode. The maximum hourly ozone concentrations are 141 ppb on June 23, 142 ppb on June 24, and 151 on June 25. The results for the August episode are shown in Figure 6. The maximum hourly ozone concentrations are 128 ppb on August 27 and 156 ppb on August 28.

Table 2 shows the peak ozone concentrations for each simulation.

The differences in maximum ozone predictions between the standard UAM/CB4 and alternative UAM/CB4 are shown in Figures 7-10. For the June episode, simulations with the high flux version of CB4 show reductions in ozone almost everywhere in the domain (Figure 7). The maximum reduction in ozone level is 13 ppb, and the maximum increase in ozone concentration is 9 ppb compared to standard UAM/CB4 results. Of note, these results appear to be quiet different due to the effect of initial concentrations. With the low flux version of CB4, the results show ozone increases in most of the domain (Figure 8). For the August episode, simulations with the high flux version of CB4 show reductions in ozone in most of the domain (Figure 9). The maximum reduction in ozone level is 11 ppb on the third day, and the maximum increase in ozone concentration is 10.6 ppb on the second day. With the low flux version of CB4, the results show ozone increases in most of the domain.

NO_x/VOC Control Simulations:

In order to investigate how UAM simulations with different mechanisms response to NO_x or VOC controls, sensitivity tests were made either with 50 percent NO_x reductions or 50 percent VOC reductions. Simulations with 50 percent across-the-board reductions in VOC or NO_x emissions were carried out for each mechanism and each episode. Table 3 shows the peak ozone concentration for simulations with 50 percent NO_x emission reductions. The peak ozone concentrations from runs with 50 percent VOC emission reductions are shown in Table 4.

For 50 Percent NO_x Control --

Standard UAM/CB4 simulations (NOx1): Figure 11 shows the results for the June episode. The maximum hourly ozone concentrations are 185 ppb on June 23, 204 ppb on June 24, and 192 on June 25. The results for the August episode are shown in Figure 12. The hourly maximum ozone concentrations are 171 ppb on August 27 and 192 ppb on August 28.

The difference plots between NOx1 and Base87 for standard UAM/CB4 runs are shown in Figures 13 and 14. For the June episode (Figure 13), ozone predictions in the central domain are increased up to 94 ppb on June 23, 115 ppb on June 24, and 121 ppb on June 25. Reductions in NO_x emissions in UAM/CB4 runs result in ozone increases significantly in Los Angeles County, Orange County, northwest of Riverside County, and southwest of San Bernardino County. The largest increase is in LA County. NO_x reductions result in ozone decreases in most of Riverside County and north of San Bernardino County. For the August episode (Figure 14), ozone predictions in the central domain are increased up to 86 ppb on August 27 and 93 ppb on August 28. Again, ozone increases in many places where it occurred in June episode. However, the region for which the simulationss show ozone increasing is smaller in the August episode than in the June episode.

High flux UAM/CB4 simulations (NOx1): Figure 15 shows results for the June episode. The maximum hourly ozone concentrations are 178 ppb on June 23, 208 ppb on June 24, and 192 on June 25. The results for the August episode are shown in Figure 16. The maximum hourly ozone concentrations are 163 ppb on August 27 and 186 ppb on August 28.

The difference plots between NOx1 and Base87 for the high-flux CB4 runs are shown in Figures 17 and 18. The results show a similar pattern as for results from the standard CB4 simulations. For the June episode, reductions in NO_x emissions in UAM/CB4 runs result in ozone increasing significantly (up to 125 ppb on second day) in Los Angeles County, Orange County, northwest of Riverside County, and southwest of San Bernardino County. The largest increase is in LA County. NO_x reductions result in ozone decreases in most of Riverside County and north of San Bernardino County. For the August episode, ozone predictions in the central domain are increased up to 93 ppb on third day. Again, predicted ozone tends to show increases in the places where it occurred in June episode.

Low flux UAM/CB4 simulations (NOx1): Figure 19 shows results for the June episode. The maximum hourly ozone concentrations are 177 ppb on June 23, 195 ppb on June 24, and 173 on June 25. The results for the August episode are shown in Figure 20. The maximum hourly ozone concentrations are 171 ppb on August 27 and 187 ppb on August 28.

The difference plots between NOx1 and Base87 for the low-flux CB4 runs are shown in Figures 21 and 22. Again, the results show a similar pattern to the results seen from the standard CB4 simulations. Reductions in NO_x emissions in UAM/CB4 runs result in significant ozone increases in places where it occurred for standard CB4 simulations . The largest increase is in LA County. NO_x reductions result in ozone decreases in some places of Riverside County and San Bernardino County.

In summary, contour plots of the differences between Base87 and NOx1 simulations show the same patterns for all StdCB4, high-flux, and low-flux simulations. The maximum differences are larger for the June episode than for the August episode.

For 50 Percent VOC Control --

Standard UAM/CB4 simulations (VOC1): Figure 23 shows results for the June episode. The maximum hourly ozone concentrations are 130 ppb on June 23, 113 ppb on June 24, and 111 on June 25. The results for the August episode are shown in Figure 24. The maximum hourly ozone concentrations are 104 ppb on August 27 and 120 ppb on August 28.

High flux UAM/CB4 simulations (VOC1): Figure 25 shows results for the June episode. The maximum hourly ozone concentrations are 134 ppb on June 23, 103 ppb on June 24, and 105 on June 25. The results for the August episode are shown in Figure 26. The maximum ozone hourly concentrations are 102 ppb on August 27 and 113 ppb on August 28.

Low flux UAM/CB4 simulations (VOC1): Figure 27 shows results for the June episode. The maximum hourly ozone concentrations are 117 ppb on June 23, 122 ppb on June 24, and 115 on June 25. The results for the August episode are shown in Figure 28. The hourly maximum ozone concentrations are 104 ppb on August 27 and 123 ppb on August 28.

For the June episode, the difference plots between VOC1 and Base87 for all three mechanisms are shown in Figures 29 and 31. It is found that reductions in VOC emissions in all UAM/CB4 runs result in ozone decrease over most area of the domain. The largest ozone reduction (up to 50 – 70 ppb) often occurred in San Bernardino County. Any increases of ozone are only about 1-5 ppb.

For the August episode, the difference plots between VOC1 and Base87 for all three mechanisms are shown in Figures 32 and 34. It is also shown that reductions in VOC emissions in all UAM/CB4 runs result in ozone decreases over most of the domain. The larger ozone reductions are up to 30 – 80 ppb.

In order to see the effect of different mechanisms on control strategies more clearly, several cells were picked based on maximum ozone concentrations in all simulation days (See Figure 57 for the locations of the cells chosen). Figures 35 – 40 show time series plots of simulated ozone concentrations in selected cells for both episodes. In these time series plots, ozone concentrations from the base year run, NO_x control run (NOx1) and VOC control run (VOC1) are presented together for each mechanism. Generally, the NOx1 run gives the highest ozone while the VOC1 run gives the lowest ozone values. Tables 5 and 6 list the maximum ozone concentrations and relative percent changes in these selected cells. For the June episode, the peak ozone is near cells fak5 and fak6. With VOC reduction, the StdCB4, high-flux and low-flux mechanisms gave similar percentage decreases in ozone. With NO_x reduction, ozone increases by 20-43 percent with low-flux mechanism, 3-19 percent with StdCB4 mechanism, and 1-8 percent with high-flux mechanism on cell fak6. In fact, on the third day ozone decreases by 5 percent with high-flux mechanism. For the August episode, the peak ozone is near cells Norcor, fak1 and fak3. With VOC control, ozone decreases by 12-40 percent with all three mechanisms. With NO_x control, ozone increases the most with the low-flux mechanism, and the least with the high-flux mechanism.

Generally, comparable decreases in peak ozone prediction are seen using the different versions of CB4 mechanism in VOC control simulations. For the NO_x-reduction simulations, ozone tends to increase the most with the low-flux mechanism, then the StdCB4 mechanism, and the least with the high-flux mechanism.

Urban Airshed Model with FCM Simulations

A special version of the UAM with flexible chemical mechanism (FCM) coding was run on the computers at the California Air Resources Board. The same base year simulations with standard CB4, high-flux, and low-flux mechanisms were conducted. Figures 41-46 present for comparison to the standard UAM results, the ozone contour plots for UAM/FCM simulations. The peak ozone concentrations predicted by UAM/FCM are shown in Table 7. Even though the differences between ozone predicted by UAM/CB4 and ozone predicted UAM/FCM are up to ±20 ppb, the differences between ozone predicted by StdCB4 and high- and low-flux chemistries with UAM/FCM are comparable to those with UAM/CB4. Figures 47-50 show ozone difference plots for UAM/FCM simulations. The differences between UAM/CB4 and UAM/FCM are presented in Figures 51-56. Some specific species are compared further in Tables 8 and 9. Noteworthy are the hydrogen peroxide (H2O2) values, where the impacts of the low and high flux chemistries show the expected results for this radical-sink species. That is, for the low flux case less radicals end up in the hydrogen peroxide sink because fewer radicals are produced originally.

TABLE 1. Summary of changes for parameters in CHEMPARAM file.

Rxn	parameter	Std. CB4	High flux CB4	Low flux CB4	unit
9: O3 + hν → O1D	factor	60	78.	42.	per hour
38: HCHO + hν → 2 HO2 + CO	factor	60	78.	42.	per hour
45: ALD2 + hν → products	factor	60.	78.	42.	per hour
69: OPEN + hν → products	factor	542.4	705.12	379.68	per hour
74: MGLY + hν → products	factor	578.4	751.92	404.88	per hour
26: OH + NO2 → HNO3	k (298)	1009000.	1311700.	706300.	1/ppm hour
32: HO2 + HO2 → H2O2	k (298)	248640.	323232.	174048.	1/ppm hour
33: 2 HO2 + H2O → H2O2	k (298)	13.086	17.0118	9.1602	1/ppm hour
49: C2O3 + C2O3 → products	k (298)	222000.	288600.	155400.	1/ppm hour
50: C2O3 + HO2 → products	k (298)	576000.	748800.	403200.	1/ppm hour
80: XO2 + XO2 →	k (298)	120000.	156000.	84000.	1/ppm hour
86: XO2 + HO2 →	k (298)	534000.	694200.	373800.	1/ppm hour
58: O3 + OLE → x HO2 +	Stoich.	0.44	0.57	0.31	
y OH + others	Coeff	0.10	0.13	0.07	
62: O3 + ETH → x HO2 +	Stoich.	0.12	0.16	0.08	
others	Coeff				
71: O3 + OLE → x HO2 +	Stoich.	0.76	0.99	0.53	
y OH +	Coeff	0.08	0.10	0.06	
z C2O3		0.62	0.80	0.43	
+others					
77: O3 + ISOP → x HO2 +	Stoich.	0.44	0.57	0.31	
y OH + others	Coeff	0.10	0.13	0.07	

TABLE 2. Summary of peak ozone concentration (ppb) for each simulation (base year).

Date	Std. CB4	High Flux CB4	Low flux CB4
June 23, 1987	154.0	150.3	140.6
June 24, 1987	139.0	147.0	142.1
June 25, 1987	151.3	146.4	151.3
August 26, 1987	108.4	108.5	108.2
August 27, 1987	127.7	126.3	128.3
August 28, 1987	160.9	161.7	155.6

TABLE 3. Summary of peak ozone concentration (ppb) for each simulation (control simulations: NOx1).

Date	Std. CB4	High Flux CB4	Low flux CB4
June 23, 1987	184.6	178.2	176.7
June 24, 1987	203.7	207.8	194.8
June 25, 1987	192.3	192.1	173.1
August 26, 1987	108.8	108.9	108.6
August 27, 1987	171.0	162.8	170.8
August 28, 1987	192.2	186.2	186.9

TABLE 4. Summary of peak ozone concentration (ppb) for each simulation (control simulations: VOC1).

Date	Std. CB4	High Flux CB4	Low flux CB4
June 23, 1987	130.3	133.6	117.1
June 24, 1987	112.5	102.9	121.7
June 25, 1987	111.2	105.3	115.3
August 26, 1987	108.4	108.5	108.2
August 27, 1987	103.9	102.0	104.2
August 28, 1987	120.2	113.2	122.8

TABLE 5a. Maximum ozone concentration at each selected cells for June episode.

		Peak Ozone (pphm) with StdCB4			Peak Ozone (pphm) with high-flux			Peak Ozone (pphm) with low-flux		
Site	Date	O3 (base)	O3 (NOx1)	O3 (VOC1)	O3 (base)	O3 (NOx1)	O3 (VOC1)	O3 (base)	O3 (NOx1)	O3 (VOC1)
Norcor	23-Jun	6.97	8.81	6.34	7.26	8.29	6.38	6.71	9.1	6.12
	24-Jun	6.92	12.15	5.92	6.89	11.62	5.77	6.97	11.99	6.08
	25-Jun	7.76	13.9	5.78	7.89	13.21	5.5	7.69	13.88	6.1
Perris	23-Jun	8	7.17	7.87	7.63	6.79	7.41	8.46	7.56	8.35
	24-Jun	7.87	7.61	7.42	7.31	7.12	6.71	8.56	8.14	8.28
	25-Jun	10.13	8.45	8.99	9.35	7.7	8.37	10.83	9.32	9.47
Redlands	23-Jun	12.22	12.37	10.46	12.4	11.7	10.99	11.06	13.05	9.29
	24-Jun	12.58	13.16	7.39	12.89	12.14	7.6	11.71	14.16	7.32
	25-Jun	12.16	12.97	8.24	12.05	12.06	7.95	12.02	13.6	8.54
Rubidoux	23-Jun	9.47	11.09	8.54	9.7	10.23	8.61	8.8	11.83	7.92
	24-Jun	10.75	12.45	7.52	10.85	11.41	7.51	10.3	13.43	7.47
	25-Jun	12.41	12.77	9.24	12.68	11.73	9.04	12.39	13.86	9.27
fak1	23-Jun	7.13	10.74	5.32	7.37	10.22	5.54	6.9	10.89	5.19
	24-Jun	8.6	11.73	6.29	8.9	11.01	6.13	8.43	12.18	6.51
	25-Jun	9.34	11.94	6.82	9.43	11.04	6.46	9.15	12.69	7.2
fak2	23-Jun	10.34	11.4	9.11	10.32	10.51	8.7	10.07	12.02	9.16
	24-Jun	12.54	10.8	10.42	11.46	9.74	9.59	13.6	12.03	11.33
	25-Jun	11.97	12.19	9.44	11.36	11.17	8.55	12.56	13.6	10.45
fak3	23-Jun	7.42	10.13	7.13	7.12	10.16	6.69	7.88	10.03	7.56
	24-Jun	8.15	13.11	7.26	7.72	12.23	6.73	8.73	13.39	7.83
	25-Jun	8.25	10.46	7.52	7.56	10.47	6.75	9.05	9.9	8.44
fak4	23-Jun	10.73	13.35	8.31	11.41	12.67	8.89	9.58	13.53	7.59
	24-Jun	11.68	15.19	6.17	12.4	14.08	6.13	10.77	16.2	6.29
	25-Jun	12.06	13.32	8.43	12.02	12.06	8.15	12.23	14.75	8.89
fak5	23-Jun	13.96	11.47	12.28	13.34	10.47	12.27	13.29	12.85	11.31
	24-Jun	13.59	12.75	8.14	13.44	11.63	8.37	12.85	14	7.97
	25-Jun	11.79	12.03	8.2	11.39	10.77	8.1	11.86	13.5	8.61
fak6	23-Jun	11.83	13.94	9.04	12.71	12.82	9.86	10.32	14.8	8.27
	24-Jun	12.09	14.38	9.07	12.1	13.11	8.54	11.73	15.75	9.46
	25-Jun	13.5	13.95	9.14	13.26	12.54	8.59	12.85	15.65	9.56

TABLE 5b. Maximum ozone concentration at each selected cells for August episode.

		Peak Ozone (pphm) with StdCB4			Peak Ozone (pphm) with high-flux			Peak Ozone (pphm) with low-flux		
Site	Date	O3 (base)	O3 (NOx1)	O3 (VOC1)	O3 (base)	O3 (NOx1)	O3 (VOC1)	O3 (base)	O3 (NOx1)	O3 (VOC1)
Norcor	26-Aug	6.75	6.87	6.75	6.76	6.88	6.76	6.74	6.86	6.73
	27-Aug	7.58	12.11	6.06	7.75	11.52	6.1	7.42	12.2	5.96
	28-Aug	11.38	14.4	8.41	11.53	13.41	8.29	11.21	15.32	8.42
Perris	26-Aug	8.72	8.77	8.72	8.74	8.78	8.73	8.7	8.75	8.7
	27-Aug	10.72	12.13	8.9	10.53	11.36	8.31	10.57	12.99	9.41
	28-Aug	14.21	12.75	11.48	13.36	11.67	10.81	15.02	13.93	11.93
Redlands	26-Aug	9.67	9.76	9.66	9.67	9.77	9.67	9.65	9.75	9.65
	27-Aug	8.78	9.29	7.24	8.79	8.72	7.4	8.41	9.81	7
	28-Aug	10.96	10.27	8.54	10.57	9.48	8.33	11.05	11.17	8.68
Rubidoux	26-Aug	8.03	8.11	8.03	8.04	8.12	8.04	8.02	8.09	8.01
	27-Aug	10.8	14.69	7.63	11.46	13.84	7.65	9.77	15.23	7.57
	28-Aug	10.74	11.05	8.47	10.42	10.27	8.06	11.03	11.94	8.73
fak1	26-Aug	7.11	7.2	7.11	7.12	7.2	7.11	7.1	7.19	7.1
	27-Aug	9.56	14.37	6.76	10.21	13.63	6.99	8.75	14.55	6.45
	28-Aug	14.63	15.06	8.88	14.62	13.96	8.8	13.93	16.21	8.67
fak2	26-Aug	5.02	5.03	5.01	5.04	5.05	5.03	4.95	4.96	4.94
	27-Aug	7.82	6.85	7.43	7.27	6.34	6.94	8.34	7.43	7.86
	28-Aug	7.9	7.2	7.27	7.36	6.62	6.72	8.51	7.93	7.82
fak3	26-Aug	5.63	5.63	5.62	5.67	5.67	5.64	5.6	5.6	5.6
	27-Aug	12.42	11.65	9.96	12.22	10.64	9.9	12.48	12.76	9.68
	28-Aug	9.28	8.62	8.04	8.58	7.88	7.56	9.92	9.48	8.69
fak4	26-Aug	7.85	7.85	7.84	7.87	7.87	7.86	7.82	7.82	7.81
	27-Aug	8.44	7.67	7.36	8	7.05	7.12	8.67	8.4	7.44
	28-Aug	7.11	6.61	6.62	6.66	6.14	6.16	7.6	7.17	7.12
fak5	26-Aug	6.48	6.48	6.48	6.49	6.49	6.49	6.46	6.46	6.46
	27-Aug	4.98	4.4	4.93	4.62	4.12	4.55	5.45	4.8	5.37
	28-Aug	6.18	5.35	6.07	5.58	4.84	5.5	6.87	5.96	6.76
fak6	26-Aug	6.06	6.06	6.06	6.07	6.07	6.07	6.04	6.04	6.04
	27-Aug	4.68	4.23	4.72	4.41	4.11	4.42	5.02	4.5	5.07
	28-Aug	5.9	5.31	5.82	5.4	4.87	5.33	6.49	5.85	6.41

TABLE 6a. Relative percent chnages on peak ozone at each selected cells for June episode.

		StdCB4		High-flux		Low-flux	
Site	Date	O3 (NOx1)	O3 (VOC1)	O3 (NOx1)	O3 (VOC1)	O3 (NOx1)	O3 (VOC1)
Norcor	23-Jun	26.40	-9.04	14.19	-12.12	35.62	-8.79
	24-Jun	75.58	-14.45	68.65	-16.26	72.02	-12.77
	25-Jun	79.12	-25.52	67.43	-30.29	80.49	-20.68
Perris	23-Jun	-10.38	-1.63	-11.01	-2.88	-10.64	-1.30
	24-Jun	-3.30	-5.72	-2.60	-8.21	-4.91	-3.27
	25-Jun	-16.58	-11.25	-17.65	-10.48	-13.94	-12.56
Redlands	23-Jun	1.23	-14.40	-5.65	-11.37	17.99	-16.00
	24-Jun	4.61	-41.26	-5.82	-41.04	20.92	-37.49
	25-Jun	6.66	-32.24	0.08	-34.02	13.14	-28.95
Rubidoux	23-Jun	17.11	-9.82	5.46	-11.24	34.43	-10.00
	24-Jun	15.81	-30.05	5.16	-30.78	30.39	-27.48
	25-Jun	2.90	-25.54	-7.49	-28.71	11.86	-25.18
fak1	23-Jun	50.63	-25.39	38.67	-24.83	57.83	-24.78
	24-Jun	36.40	-26.86	23.71	-31.12	44.48	-22.78
	25-Jun	27.84	-26.98	17.07	-31.50	38.69	-21.31
fak2	23-Jun	10.25	-11.90	1.84	-15.70	19.36	-9.04
	24-Jun	-13.88	-16.91	-15.01	-16.32	-11.54	-16.69
	25-Jun	1.84	-21.14	-1.67	-24.74	8.28	-16.80
fak3	23-Jun	36.52	-3.91	42.70	-6.04	27.28	-4.06
	24-Jun	60.86	-10.92	58.42	-12.82	53.38	-10.31
	25-Jun	26.79	-8.85	38.49	-10.71	9.39	-6.74
fak4	23-Jun	24.42	-22.55	11.04	-22.09	41.23	-20.77
	24-Jun	30.05	-47.17	13.55	-50.56	50.42	-41.60
	25-Jun	10.45	-30.10	0.33	-32.20	20.61	-27.31
fak5	23-Jun	-17.84	-12.03	-21.51	-8.02	-3.31	-14.90
	24-Jun	-6.18	-40.10	-13.47	-37.72	8.95	-37.98
	25-Jun	2.04	-30.45	-5.44	-28.88	13.83	-27.40
fak6	23-Jun	17.84	-23.58	0.87	-22.42	43.41	-19.86
	24-Jun	18.94	-24.98	8.35	-29.42	34.27	-19.35
	25-Jun	3.33	-32.30	-5.43	-35.22	21.79	-25.60

TABLE 6b. Relative percent changes on peak ozone at each selected cells for August episode.

		StdCB4		High-flux		Low-flux	
Site	Date	O3 (NOx1)	O3 (VOC1)	O3 (NOx1)	O3 (VOC1)	O3 (NOx1)	O3 (VOC1)
Norcor	26-Aug	1.78	0.00	1.78	0.00	1.78	-0.15
	27-Aug	59.76	-20.05	48.65	-21.29	64.42	-19.68
	28-Aug	26.54	-26.10	16.31	-28.10	36.66	-24.89
Perris	26-Aug	0.57	0.00	0.46	-0.11	0.57	0.00
	27-Aug	13.15	-16.98	7.88	-21.08	22.89	-10.97
	28-Aug	-10.27	-19.21	-12.65	-19.09	-7.26	-20.57
Redlands	26-Aug	0.93	-0.10	1.03	0.00	1.04	0.00
	27-Aug	5.81	-17.54	-0.80	-15.81	16.65	-16.77
	28-Aug	-6.30	-22.08	-10.31	-21.19	1.09	-21.45
Rubidoux	26-Aug	1.00	0.00	1.00	0.00	0.87	-0.12
	27-Aug	36.02	-29.35	20.77	-33.25	55.89	-22.52
	28-Aug	2.89	-21.14	-1.44	-22.65	8.25	-20.85
fak1	26-Aug	1.27	0.00	1.12	-0.14	1.27	0.00
	27-Aug	50.31	-29.29	33.50	-31.54	66.29	-26.29
	28-Aug	2.94	-39.30	-4.51	-39.81	16.37	-37.76
fak2	26-Aug	0.20	-0.20	0.20	-0.20	0.20	-0.20
	27-Aug	-12.40	-4.99	-12.79	-4.54	-10.91	-5.76
	28-Aug	-8.86	-7.97	-10.05	-8.70	-6.82	-8.11
fak3	26-Aug	0.00	-0.18	0.00	-0.53	0.00	0.00
	27-Aug	-6.20	-19.81	-12.93	-18.99	2.24	-22.44
	28-Aug	-7.11	-13.36	-8.16	-11.89	-4.44	-12.40
fak4	26-Aug	0.00	-0.13	0.00	-0.13	0.00	-0.13
	27-Aug	-9.12	-12.80	-11.88	-11.00	-3.11	-14.19
	28-Aug	-7.03	-6.89	-7.81	-7.51	-5.66	-6.32
fak5	26-Aug	0.00	0.00	0.00	0.00	0.00	0.00
	27-Aug	-11.65	-1.00	-10.82	-1.52	-11.93	-1.47
	28-Aug	-13.43	-1.78	-13.26	-1.43	-13.25	-1.60
fak6	26-Aug	0.00	0.00	0.00	0.00	0.00	0.00
	27-Aug	-9.62	0.85	-6.80	0.23	-10.36	1.00
	28-Aug	-10.00	-1.36	-9.81	-1.30	-9.86	-1.23

TABLE 7. Summary of peak ozone concentration (ppb) for each simulation with UAM/FCM (base year).

Date	Std. CB4	High Flux CB4	Low flux CB4
June 23, 1987	143.4	148.8	126.1
June 24, 1987	133.7	128.8	143.6
June 25, 1987	147.9	142.4	146.9
August 26, 1987	108.5	108.6	108.3
August 27, 1987	135.4	133.1	136.1
August 28, 1987	176.1	175.60	171.1

TABLE 8. Comparison between three versions of CB4 for June 25, 1987 using the UAM/FCM.

Pollutants	Predicted Concentration (ppb)		
	Low-Flux	Base	High-Flux
O3	146.9	147.9	142.4
NO2	309.8	305.1	300.7
NO	1241.1	1248.2	1254.9
H2O2	5.3	7.3	9.1
HNO3	25.3	24.2	26.9
PAN	3.1	3.4	3.4

TABLE 9a. Comparison between three versions of CB4 for June 25, 1987 using the Standard UAM.

Pollutants	Predicted Concentration (ppb)		
	Low-Flux	Base	High-Flux
O3	151.3	151.3	146.4
NO2	309.4	303.7	298.5
NO	1243.1	1251.4	1259.2
H2O2	6.1	8.2	10.1
HNO3	22.8	24.6	27.4
PAN	5.0	5.1	5.1

TABLE 9b. Comparison between three versions of CB4 for August 28, 1987 using the UAM/FCM.

Pollutants	Predicted Concentration (ppb)		
	Low-Flux	Base	High-Flux
O3	155.6	160.9	161.7
NO2	99.7	96.8	94.3
NO	311.8	315.1	318.0
H2O2	4.6	6.4	8.0
HNO3	34.1	35.1	35.8
PAN	4.0	4.3	4.4

CONCLUSIONS AND RECOMENDATIONS

Uncertainty in airshed models due to uncertainties in the chemical mechanism used, has been addressed in this study by altering the free radical flux used in the standard Carbon Bond Mechanism version 4 (CB4). The reactions governing radical sources and sinks were changed to either increase the flux of radicals by 30 percent or to lower the flux by 30 percent. This magnitude of flux variance is based on a literature review conducted during Phase I. The intention of changing the flux to address uncertainty was to maintain similar radical steady-state levels during simulations of either the smog chamber validation tests or the base case simulations of the UAM itself.

Other methods of addressing the uncertainty in UAM simulations due to chemistry are possible. Uncertainty is often assumed to be a fairly random phenomenon and others have addressed the impact of uncertainties by multiple tests using Monte Carlo variations of the key parameters. However, a key ground rule for this particular study has been that the smog chamber tests must still be acceptable for an alternate version of the chemistry to be considered for the UAM tests in Phase II. A comprehensive smog chamber screening of random versions of the mechanism would be costly and there is no indication that randomly selected candidates, which might pass the smog chamber screening, would lead to significantly different control strategy implications than the standard mechanism.

Another source of differences in UAM-based simulations that some might call a form of uncertainty would stem from the use of a newly developed standard chemical mechanism. Such a new mechanism could be developed that incorporated the latest scientific information. But this new mechanism would have to be developed in such as way as to still be capable of simulating the same database used to test the original CB4, plus any new data that perhaps the original CB4 cannot simulate acceptably. A related ground rule of the present study has been not to develop a new mechanism but to address the uncertainties in the original CB4 as still used in regulatory applications of the UAM.

As a preliminary indication of the expected UAM-based control strategy changes, box-model simulations were conducted as part of Phase I. Those box model tests indicated that the alternative versions should give different control strategy implications, especially when the scenario involves changing the emissions ratio of volatile organic compound (VOC) to nitrogen oxides (NOx). Such results were considered reasonable because many radical sources tend to come from the organics (e.g., formaldehyde photolysis), while a key radical sink comes from the NOx (i.e., the reaction of OH with NO_2). Exceptions, however, would be first that ozone itself is also an important radical source (through the ozone photolysis to O^1D followed by reaction with water) and second that radical-radical sinks are important when NOx concentrations become low. Therefore, the control scenarios chosen for the UAM simulations performed in Phase II involved changing the emissions ratio; this was accomplished by reducing either VOC or NOx by 50 percent compared to the base case emissions for two 1987 episodes in the South Coast Air Basin (SoCAB). The box model tests further indicated that the strongest impacts on controls might be seen for regions where the base VOC-to-NOx ratios are low, which is another reason to select the SoCAB for UAM testing.

The results from the UAM simulations show many (but minor) variations throughout the SoCAB. There appears to be no consistent pattern for the two alternative representations of the CB4 mechanism. As expected, they each tend to provide similar base-case results, which implies that overall UAM model performance would not be significantly different. However, it was unexpected to find that even though control strategy simulations varied between the three versions of chemistry, the high and low-flux alternates did not produce consistent impacts compared to the standard chemistry. For example, for the 25 June, 1987, episode-day at the Norcor monitoring site a 50 percent VOC control showed the greatest percent ozone reduction using the high flux chemistry, but at the Perris site high flux chemistry gave the least impact from VOC control. Another type of example was seen for local areas that tend to show simulated ozone increases from NOx reductions: for 25 June, 1987, at the Rubidoux monitoring site, the high flux chemistry was the only version to show any ozone reduction (from NOx control), but at a site near Azusa, high flux chemistry produced the greatest ozone increase from NOx reduction. Apparently, consistent patterns predicted by box models can be obscured in grid models that have more complex emissions variations in time and space. Also in grid models, transport time to specific sites is fixed by the meteorology, but ozone formation timing can be affected by radical flux, so that an impact predicted by a box model might occur at a different site in a grid model.

As part of this study, results from a special coding of the UAM (that can use flexible chemical mechanisms or FCM) were compared to the results generated by the standard UAM code. Although the two codes produce similar trends with the high and low flux versions of the CB4 chemistry, there are unexplained reasons for differences in some species (e.g., PAN). Control strategy simulations between the two codes were not available, but it is recommended that these be compared in the future. Also it may be worthwhile to determine which of the two codes give more “correct” results.

Although beyond the scope of the present study, it is recommended that the computer output files generated here be analyzed to determine the impact of the UAM sensitivity runs performed might have on ozone concentrations relating to the new 8-hour standard.

References

Whitten, G.Z. and J.P. Killus (1998) "Effect of Chemical Mechanism Uncertainty on Airshed Model Results" Phase I Final Report to California Air Resources Board, Report No. SYSAPP-97/57,Systems Applications International, Inc., San Rafael, California.

Appendix

FIGURES

List of Figures

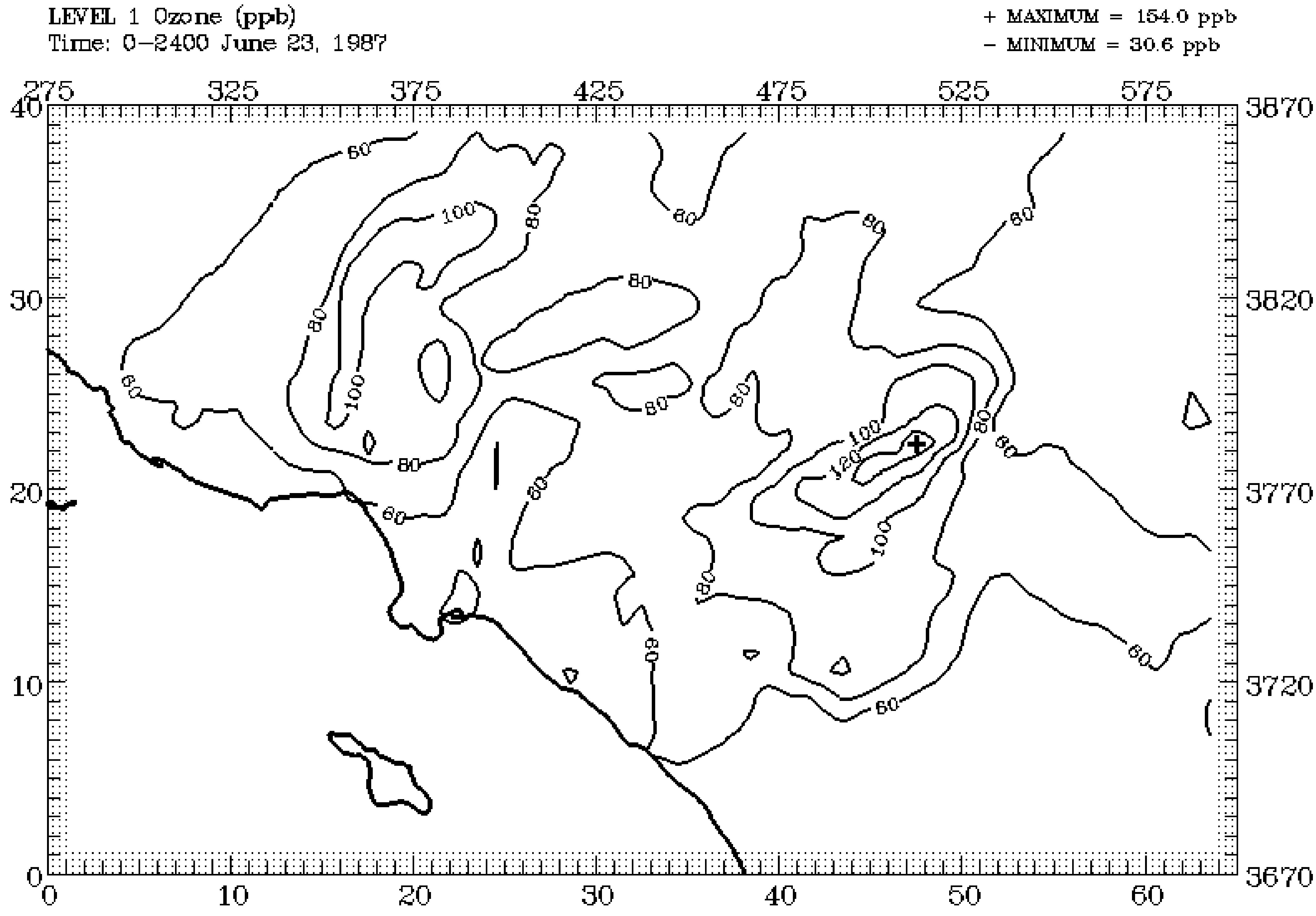

Figure 1a. Maximum simulated ozone concentrations for base year run with standard CB4- June 23, 1987.

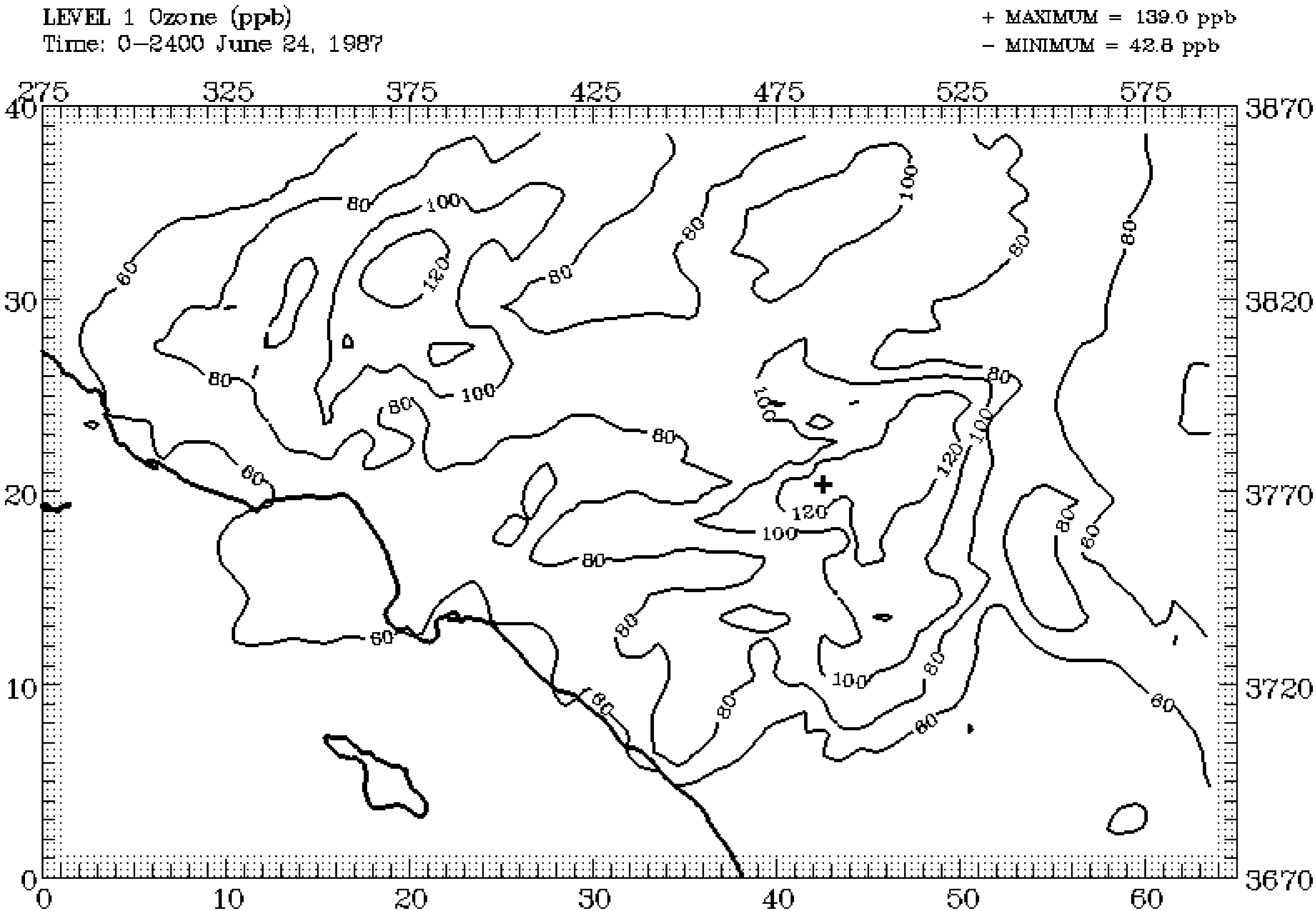

Figure 1b. Maximum simulated ozone concentrations for base year run with standard CB4-
June 24, 1987.

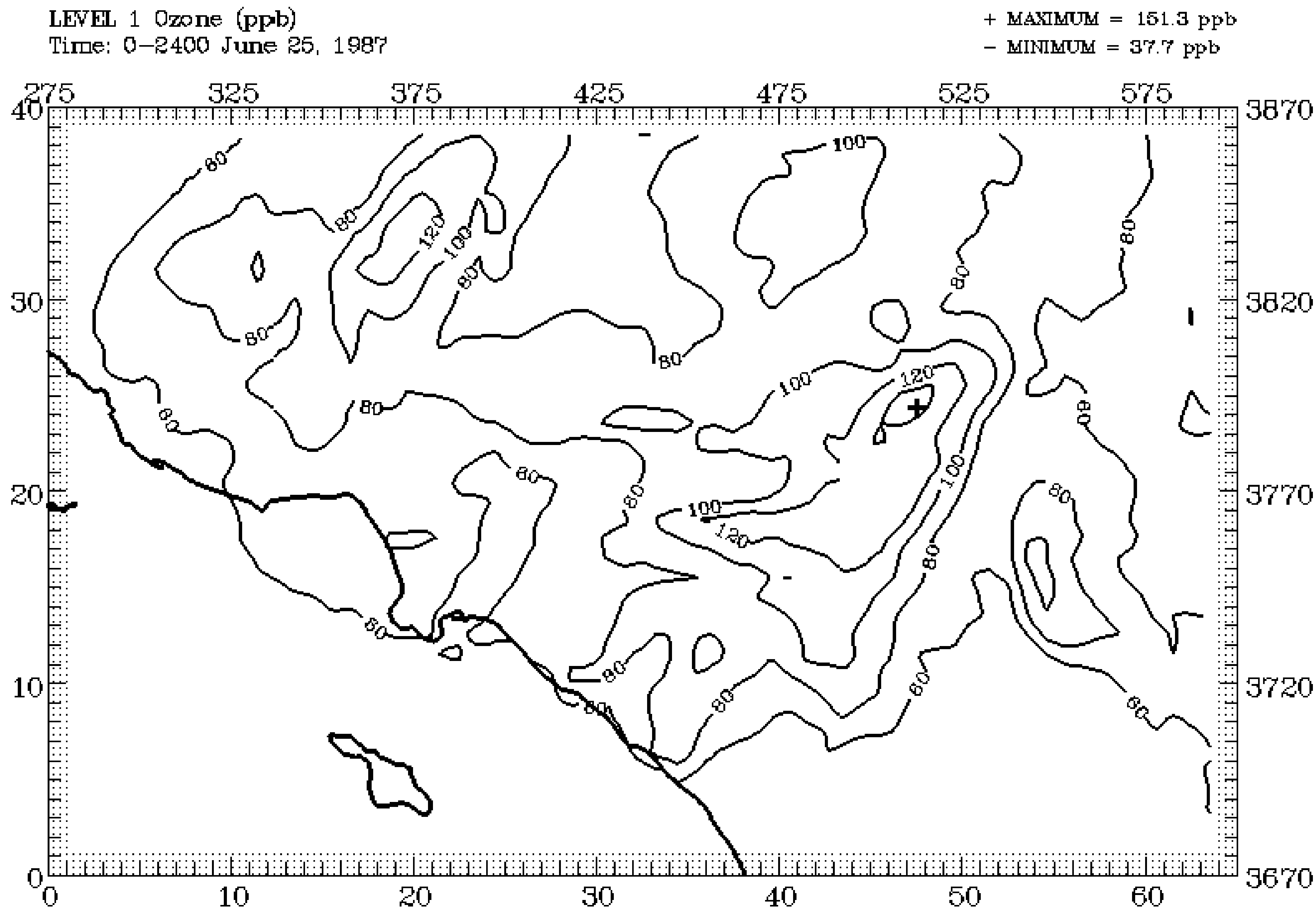

Figure 1c. Maximum simulated ozone concentrations for base year run with standard CB4-
June 25, 1987.

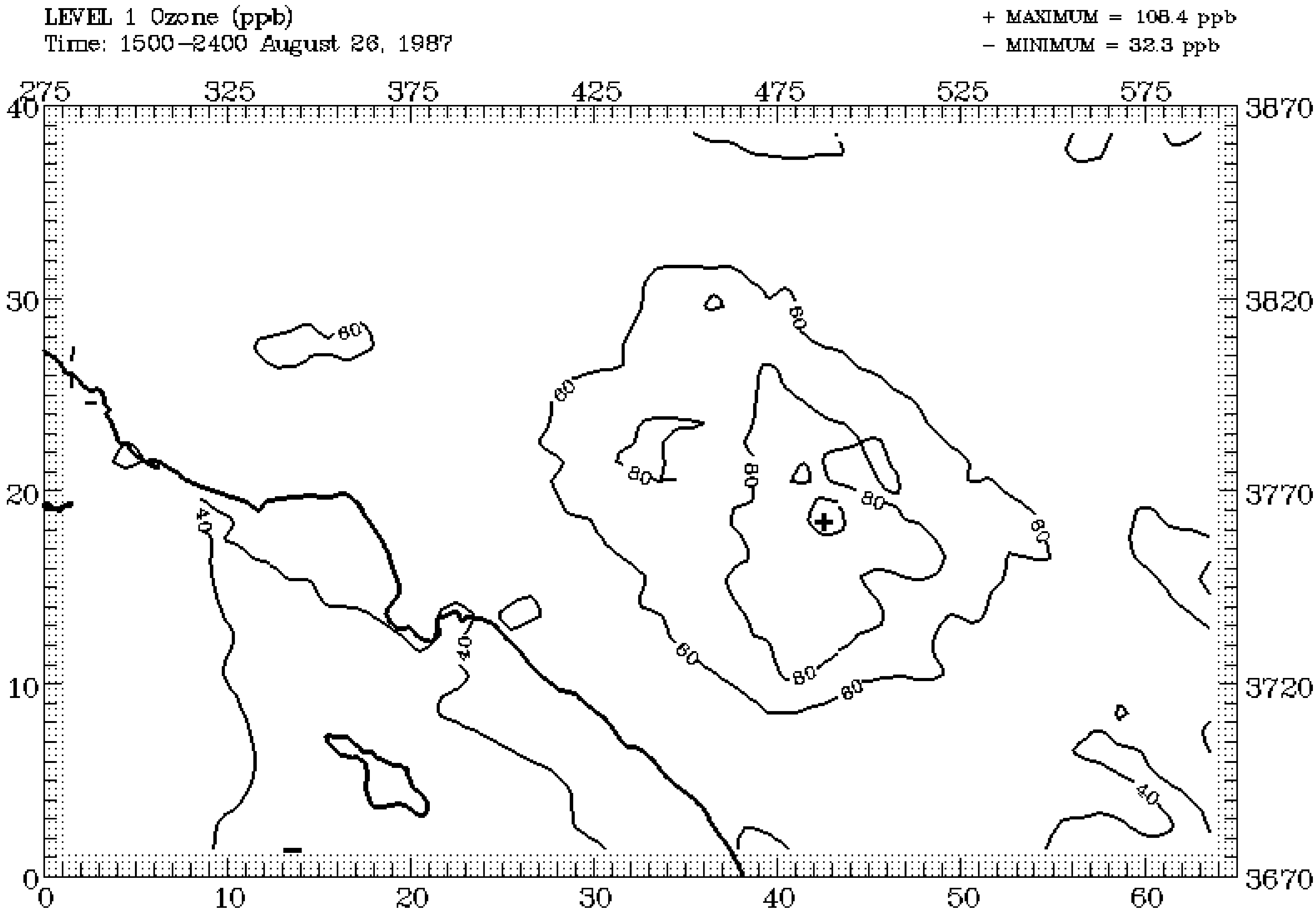

Figure 2a. Maximum simulated ozone concentrations for base year run with Standard CB4- August 26, 1987.

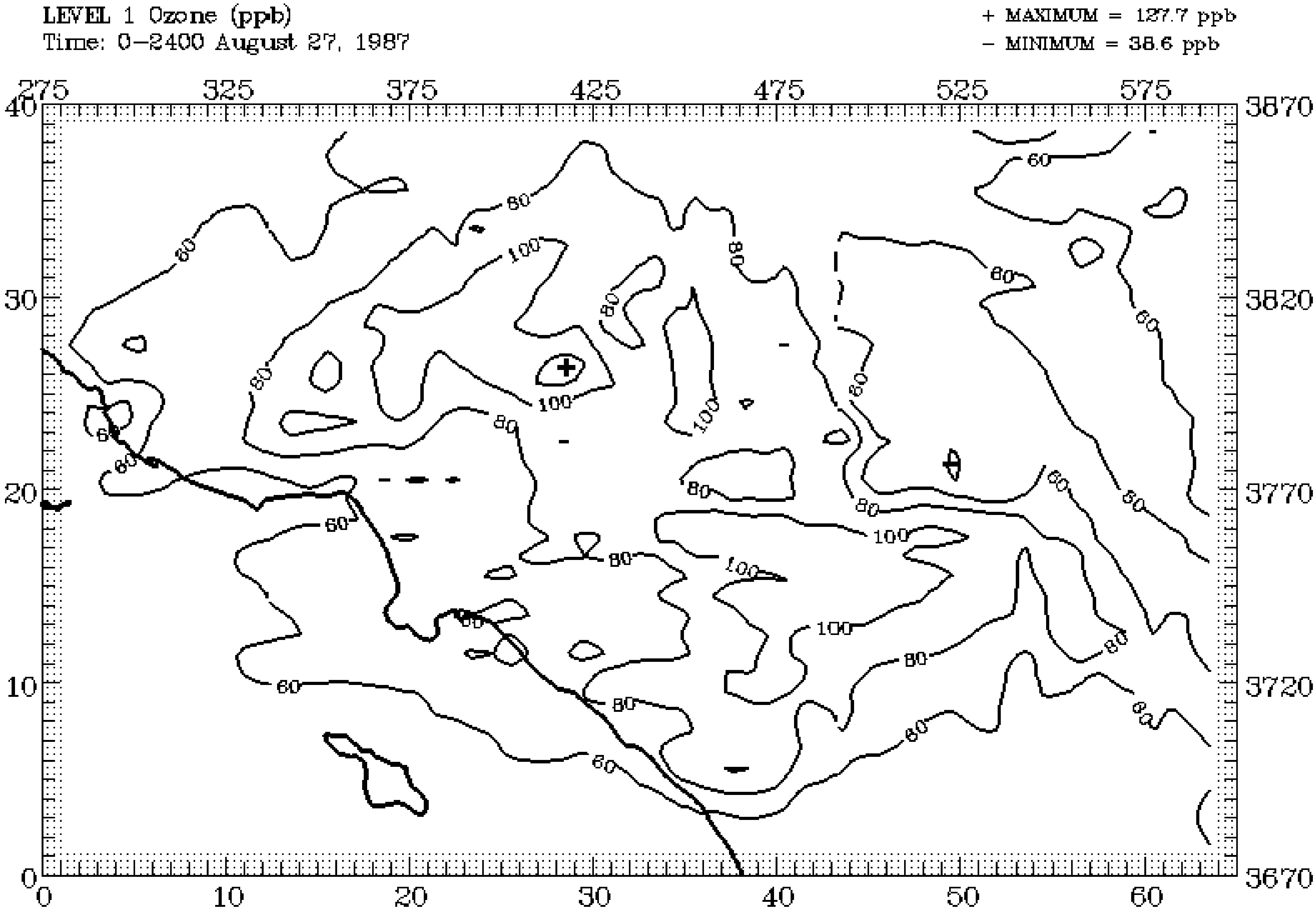

Figure 2b. Maximum simulated ozone concentrations for base year run with standard CB4- August 27, 1987.

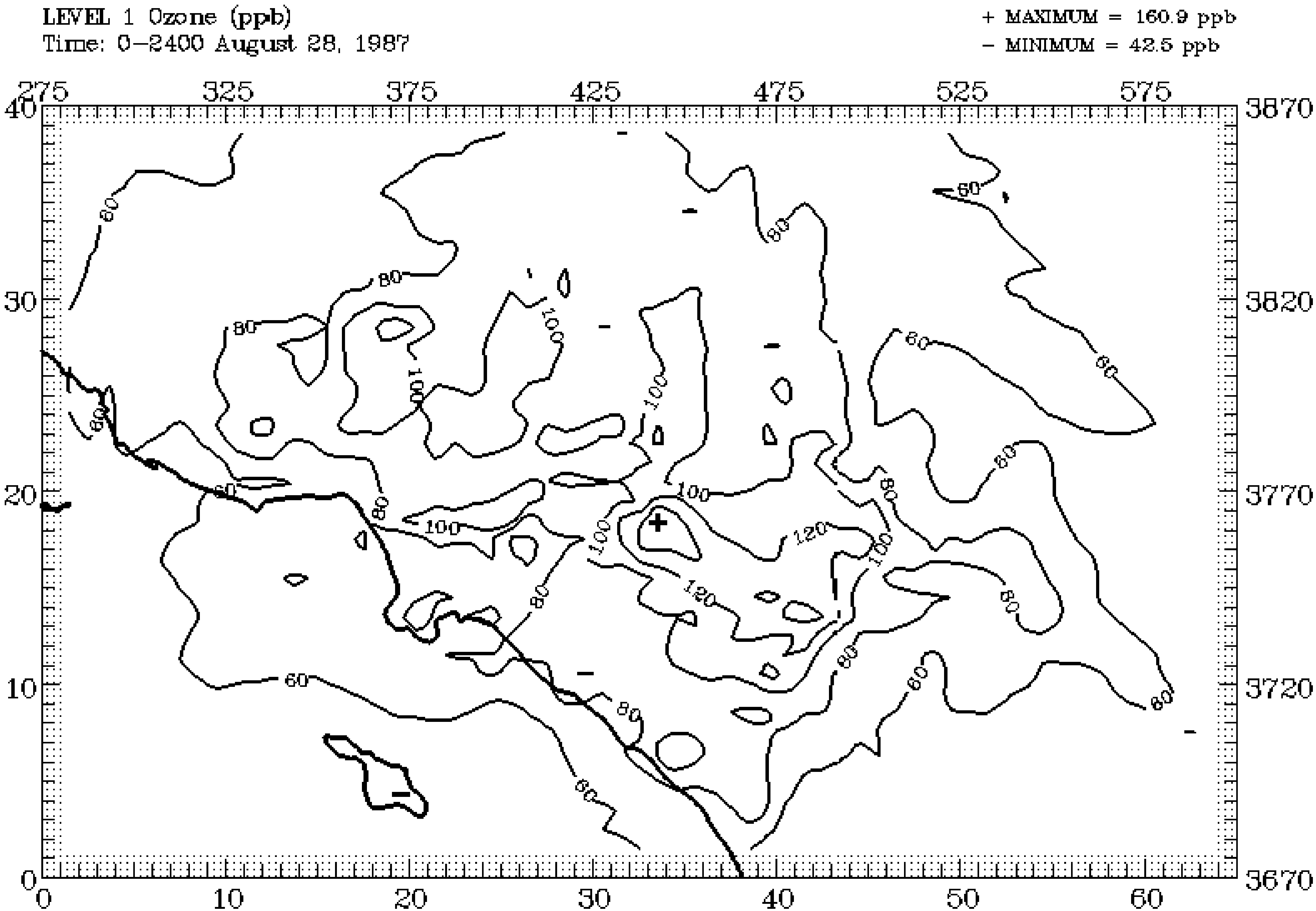

Figure 2c. Maximum simulated ozone concentrations for base year run with standard CB4-
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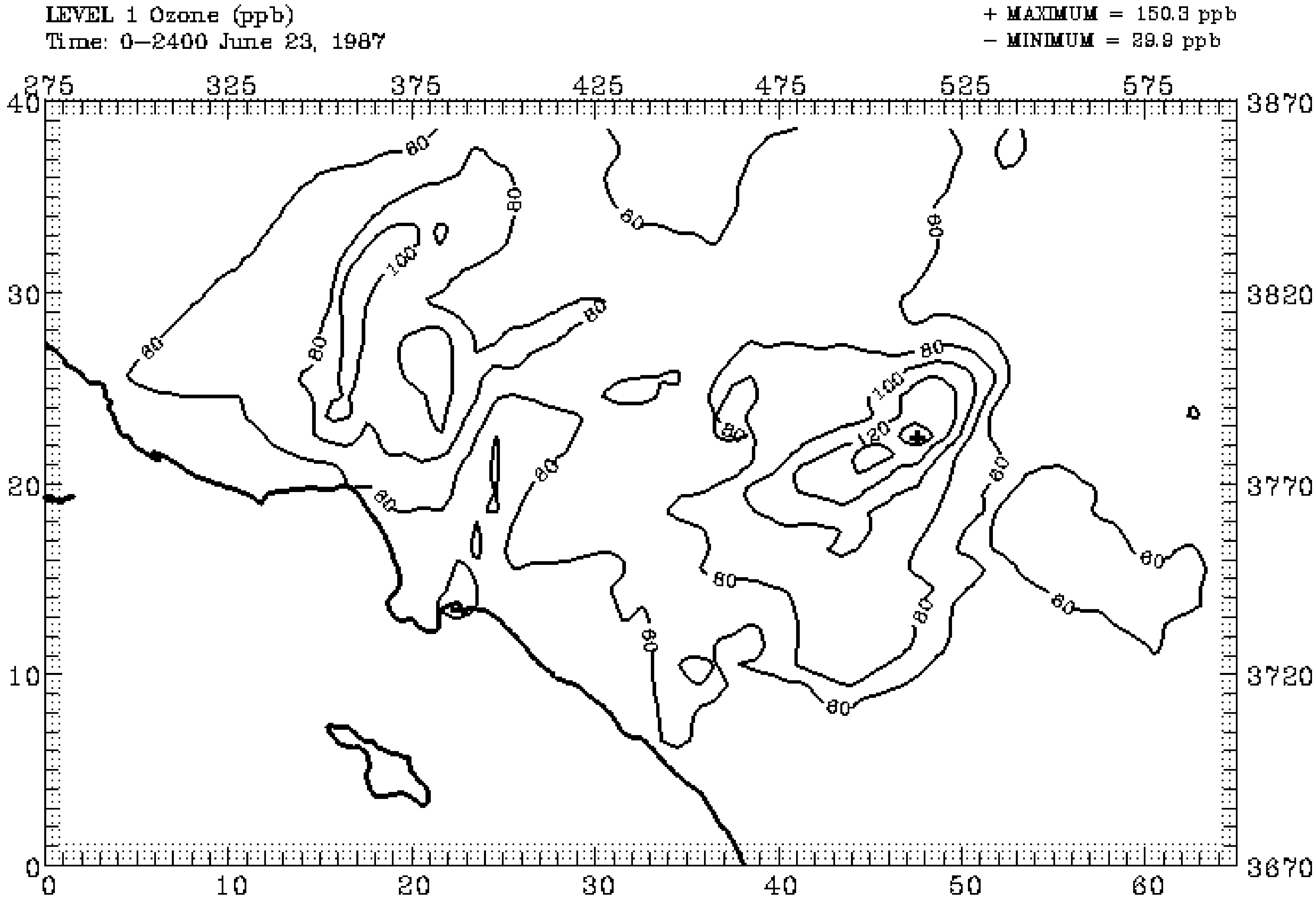


Figure 3a. Maximum simulated ozone concentrations for base year run with highflux CB4 - June 23, 1987.

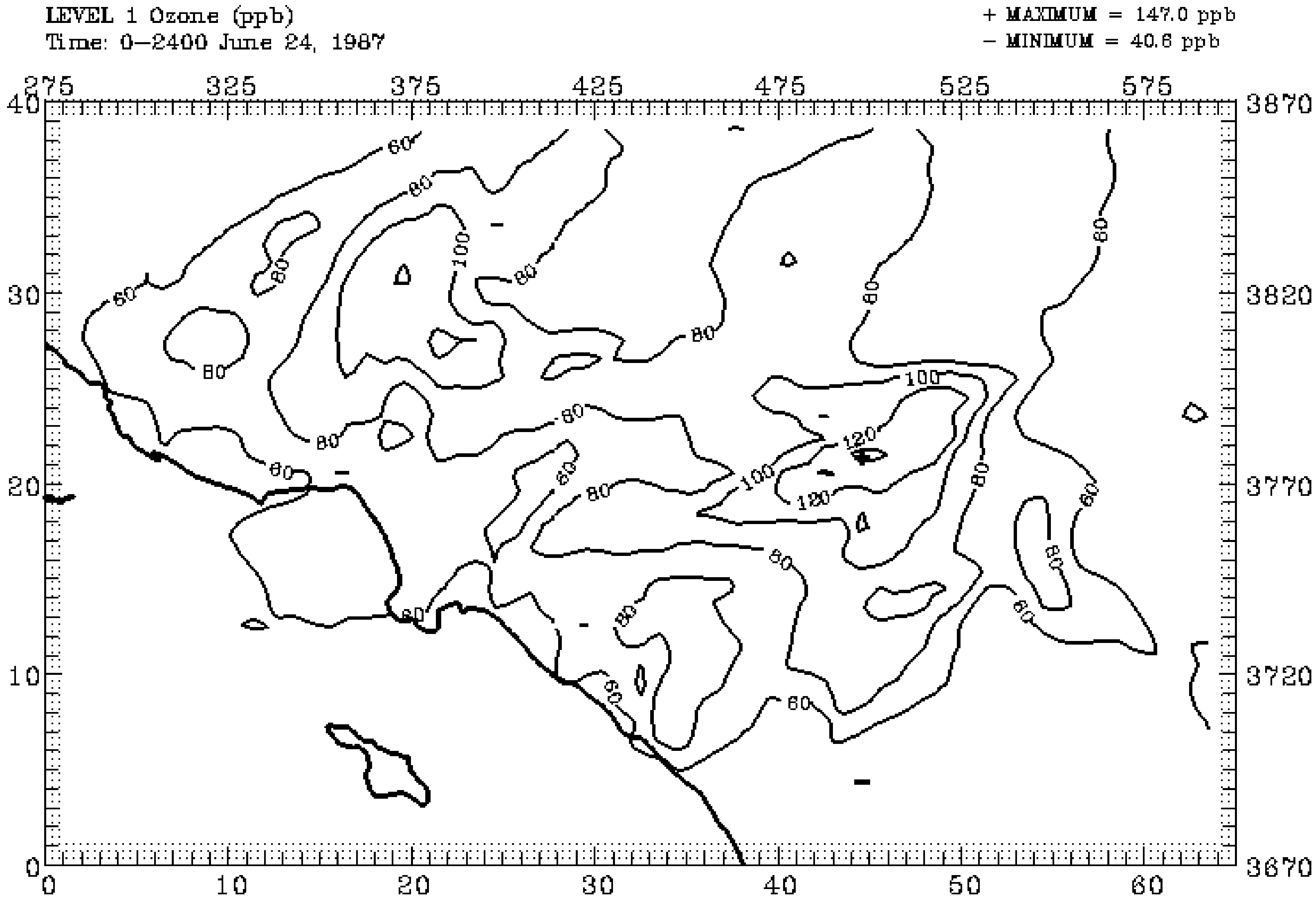


Figure 3b. Maximum simulated ozone concentrations for base year run with highflux CB4 - June 24, 1987.

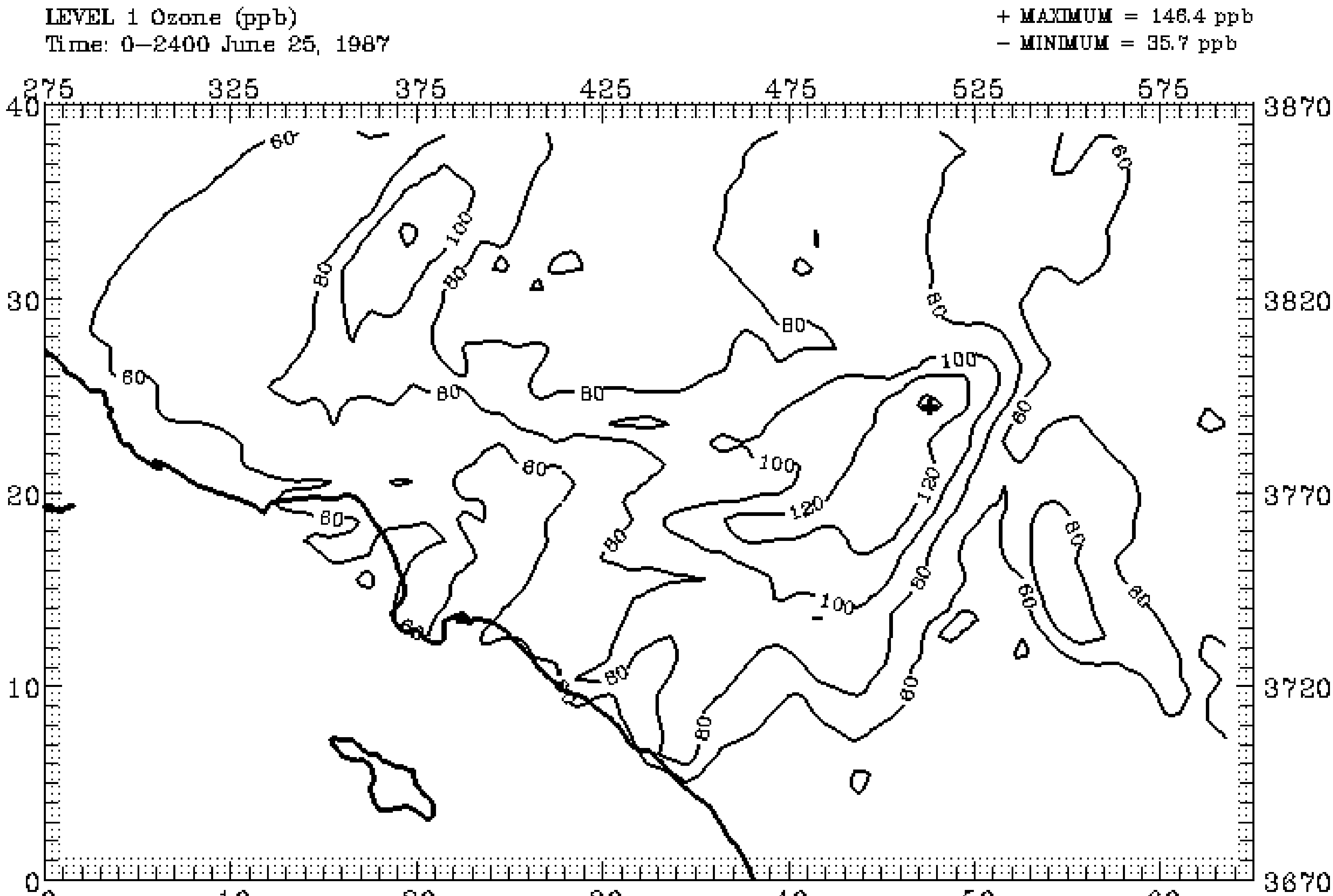


Figure 3c. Maximum simulated ozone concentrations for base year run with highflux CB4 - June 25, 1987.

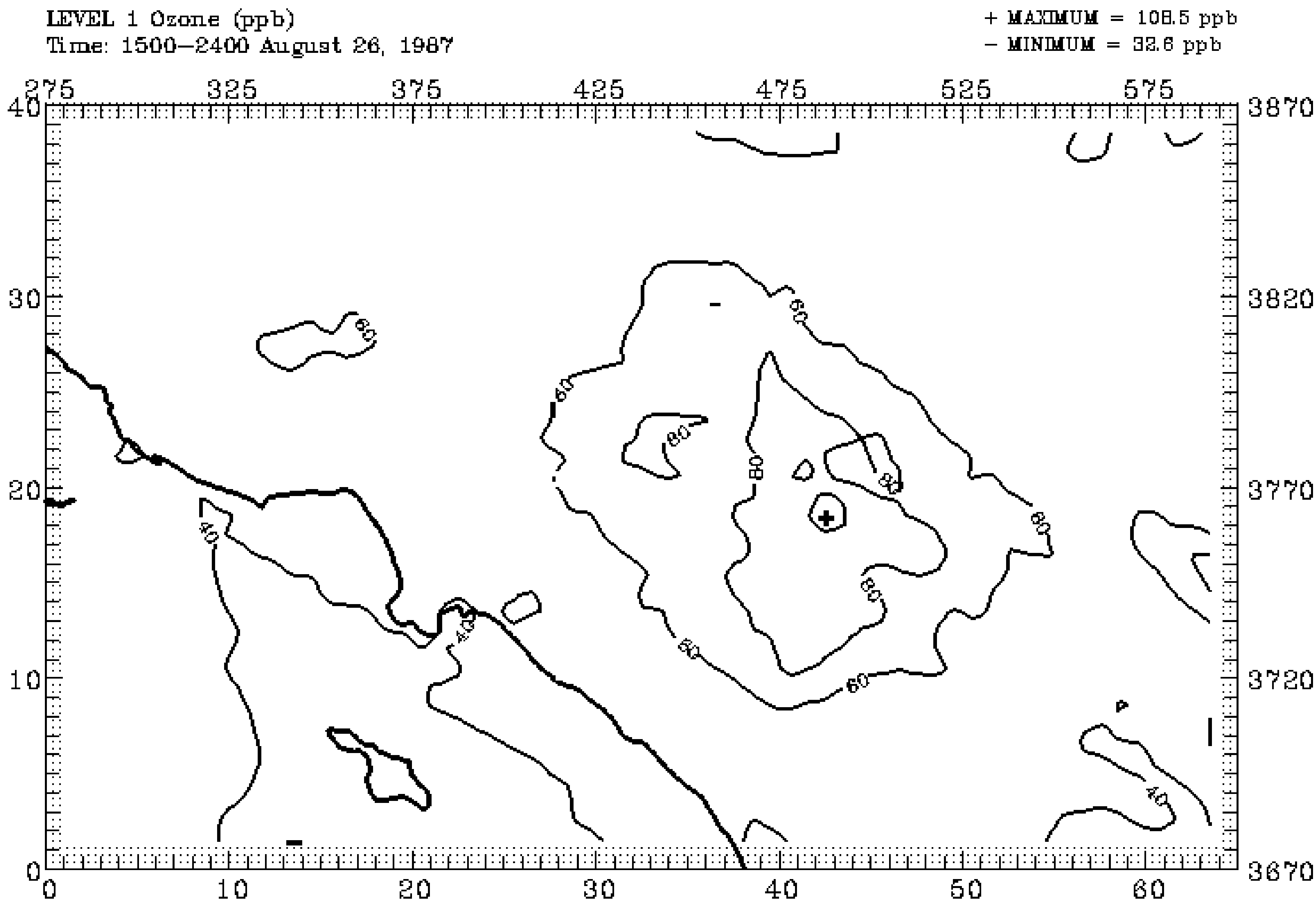


Figure 4a. Maximum simuated ozone concentrations for base year run with highflux CB4 - August 26, 1987.

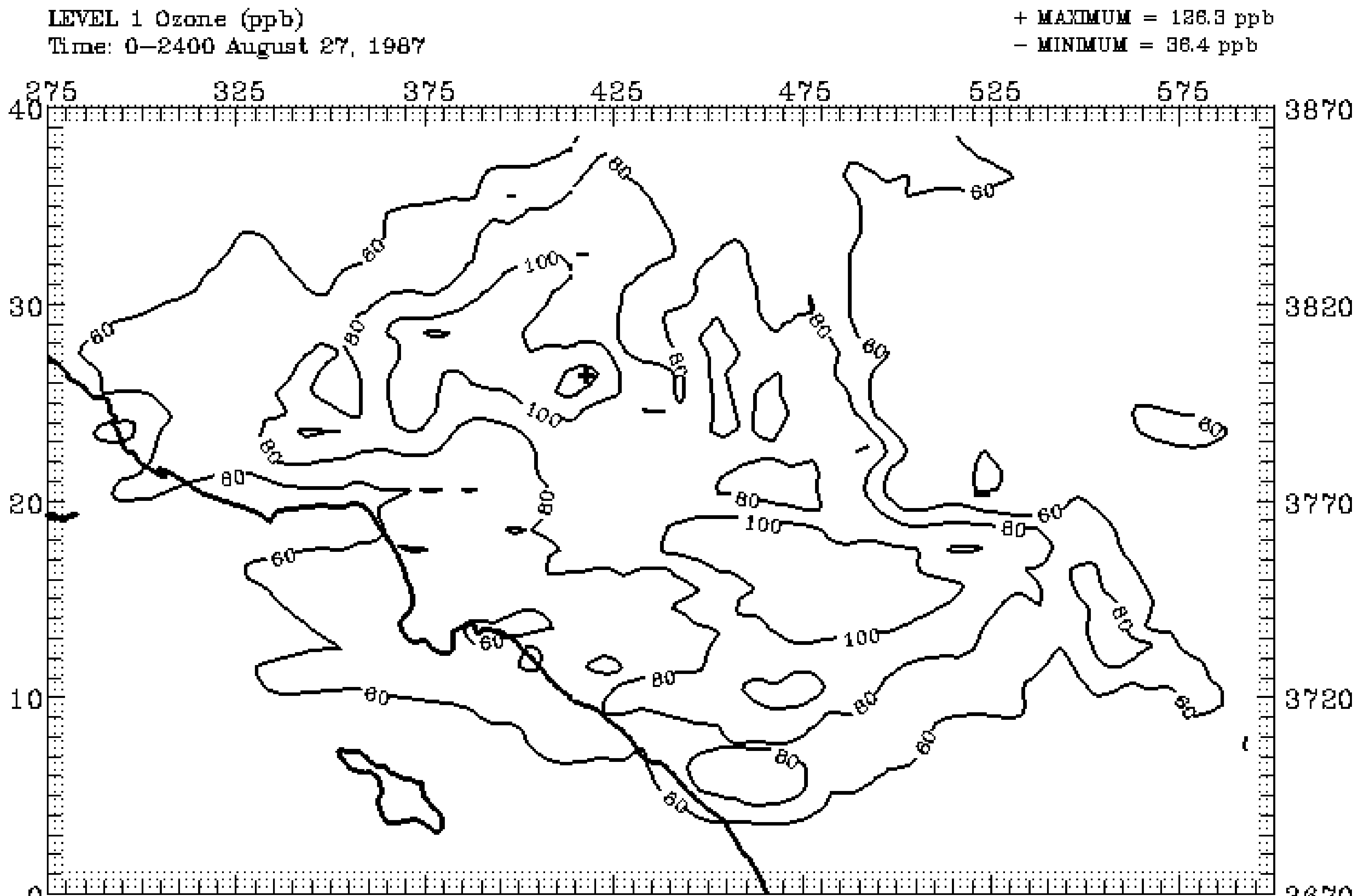


Figure 4b. Maximum simulated ozone concentrations for base year run with highflux CB4 - August 27, 1987.

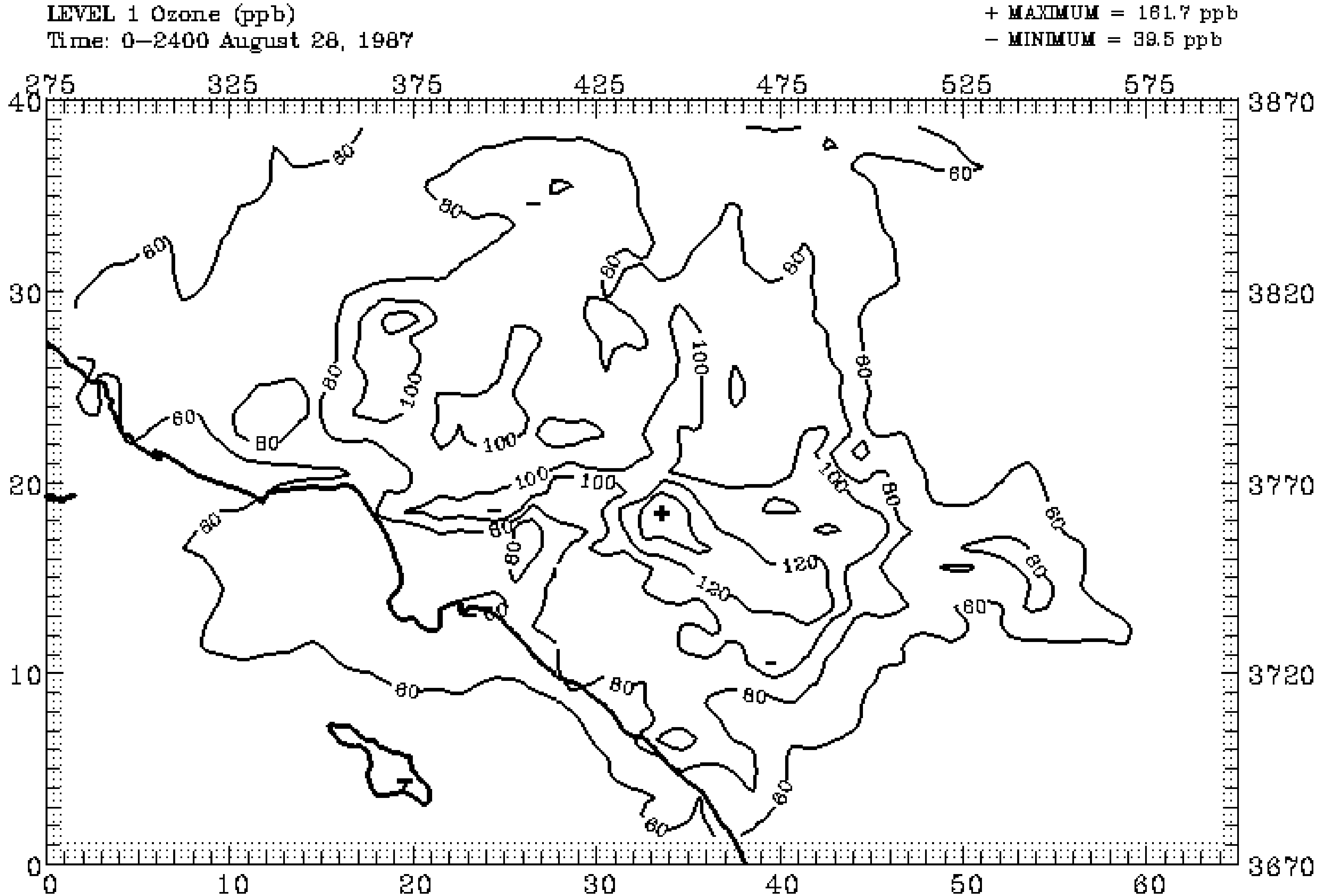


Figure 4c. Maximum simulated ozone concentrations for base year run with highflux CB4 - August 28, 1987.

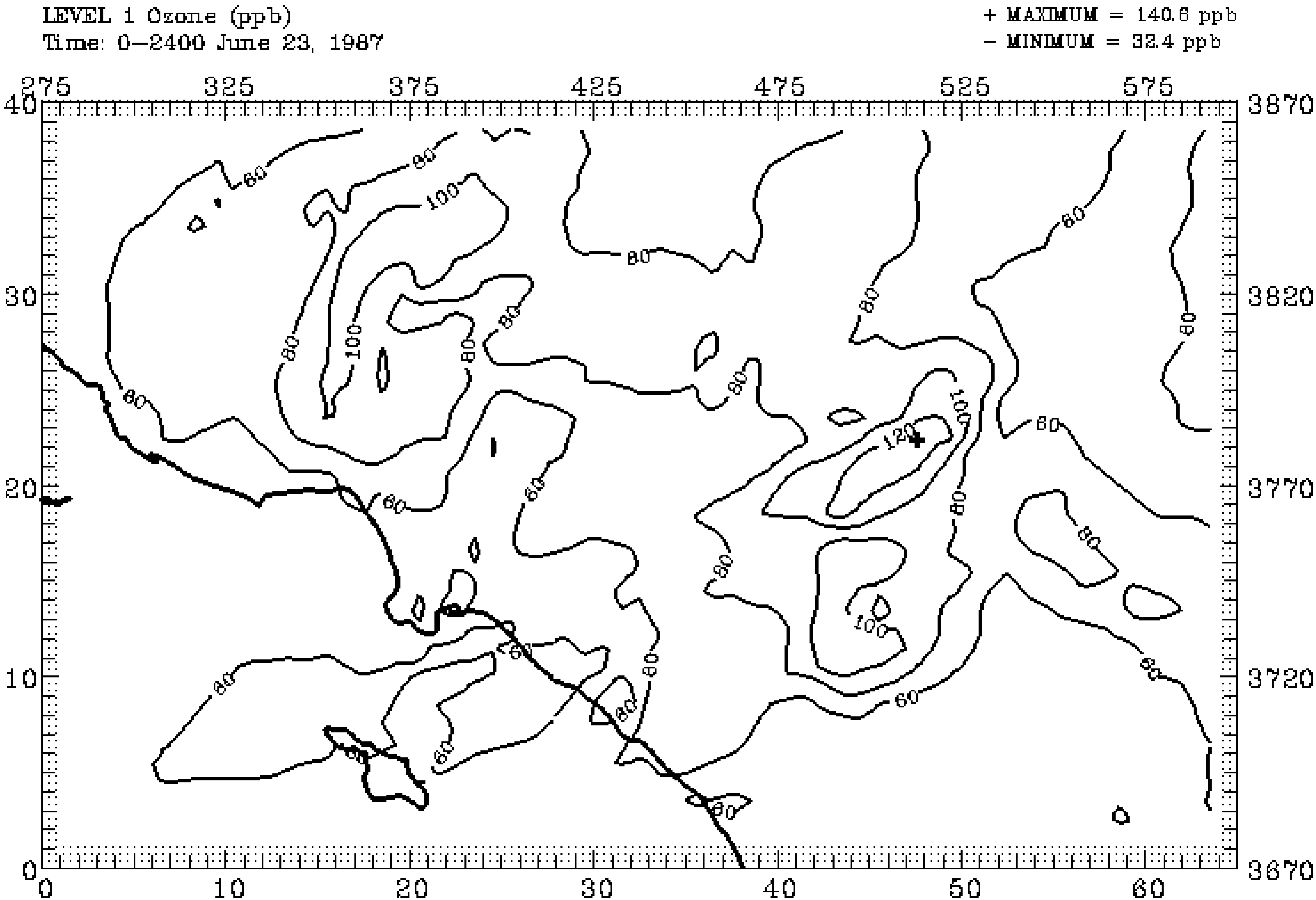


Figure 5a. Maximum simulated ozone concentrations for base year run with lowflux CB4 - June 23, 1987.

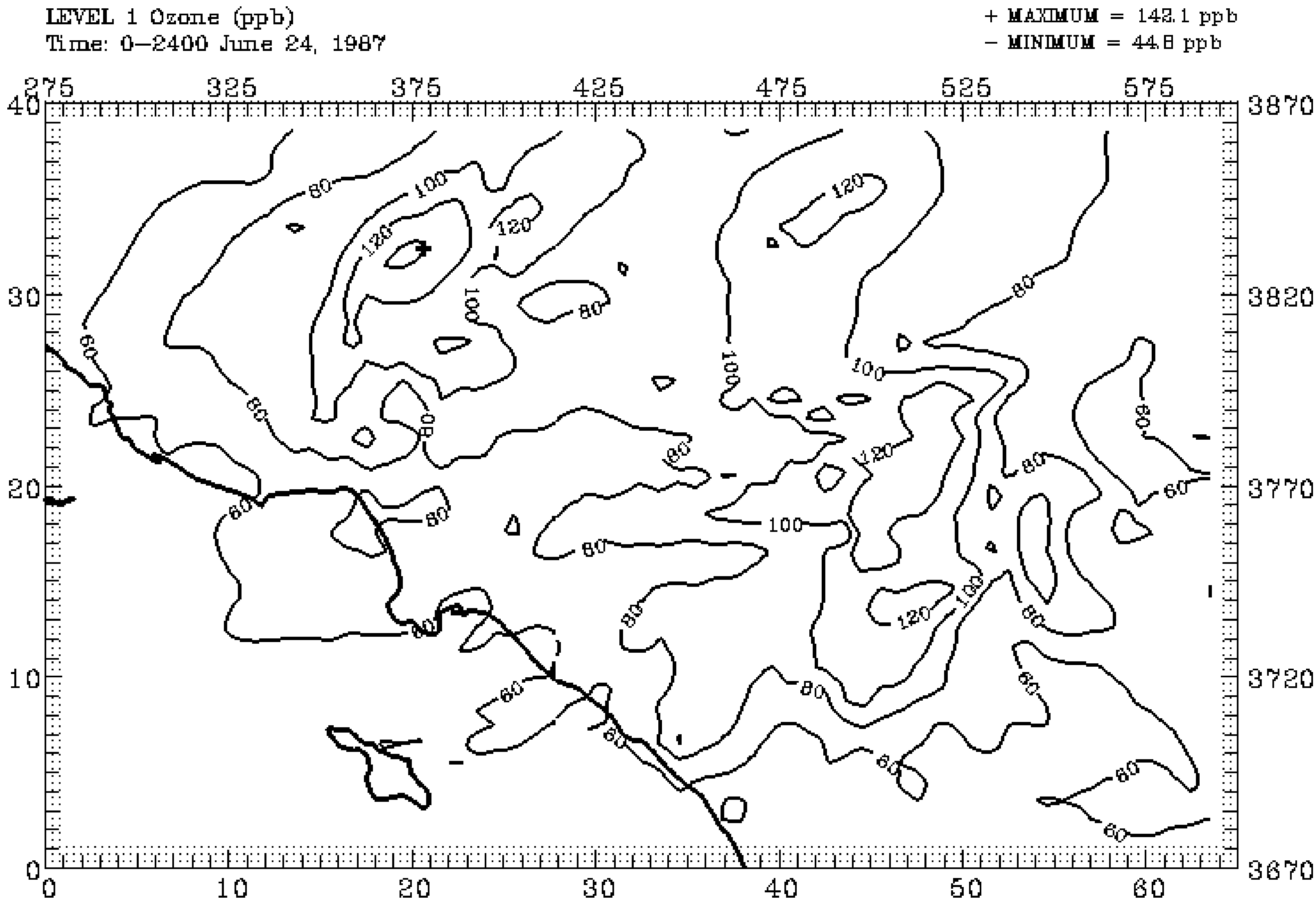
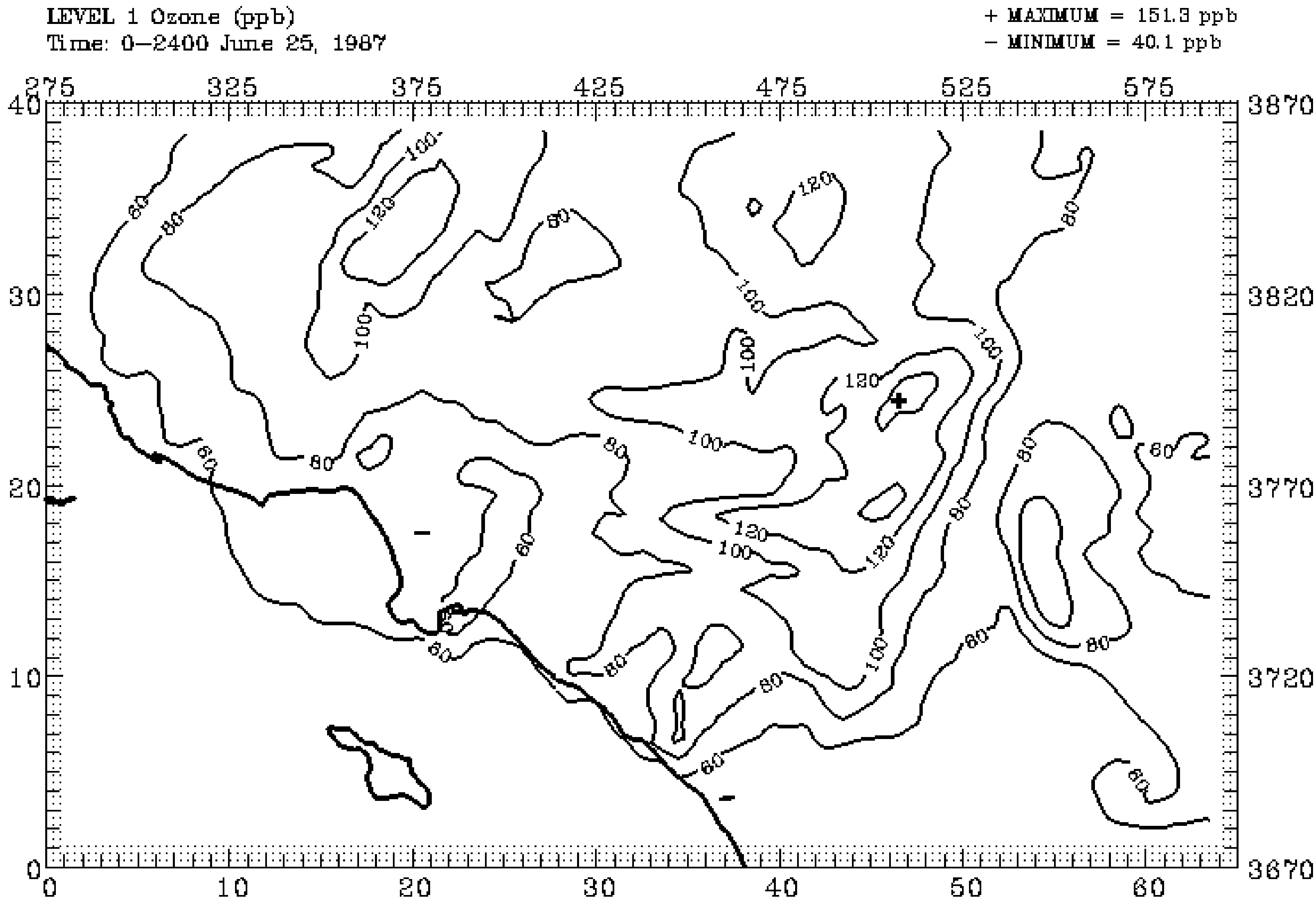


Figure 5b. Maximum simulated ozone concentrations for base year run with lowflux CB4 - June 24, 1987.



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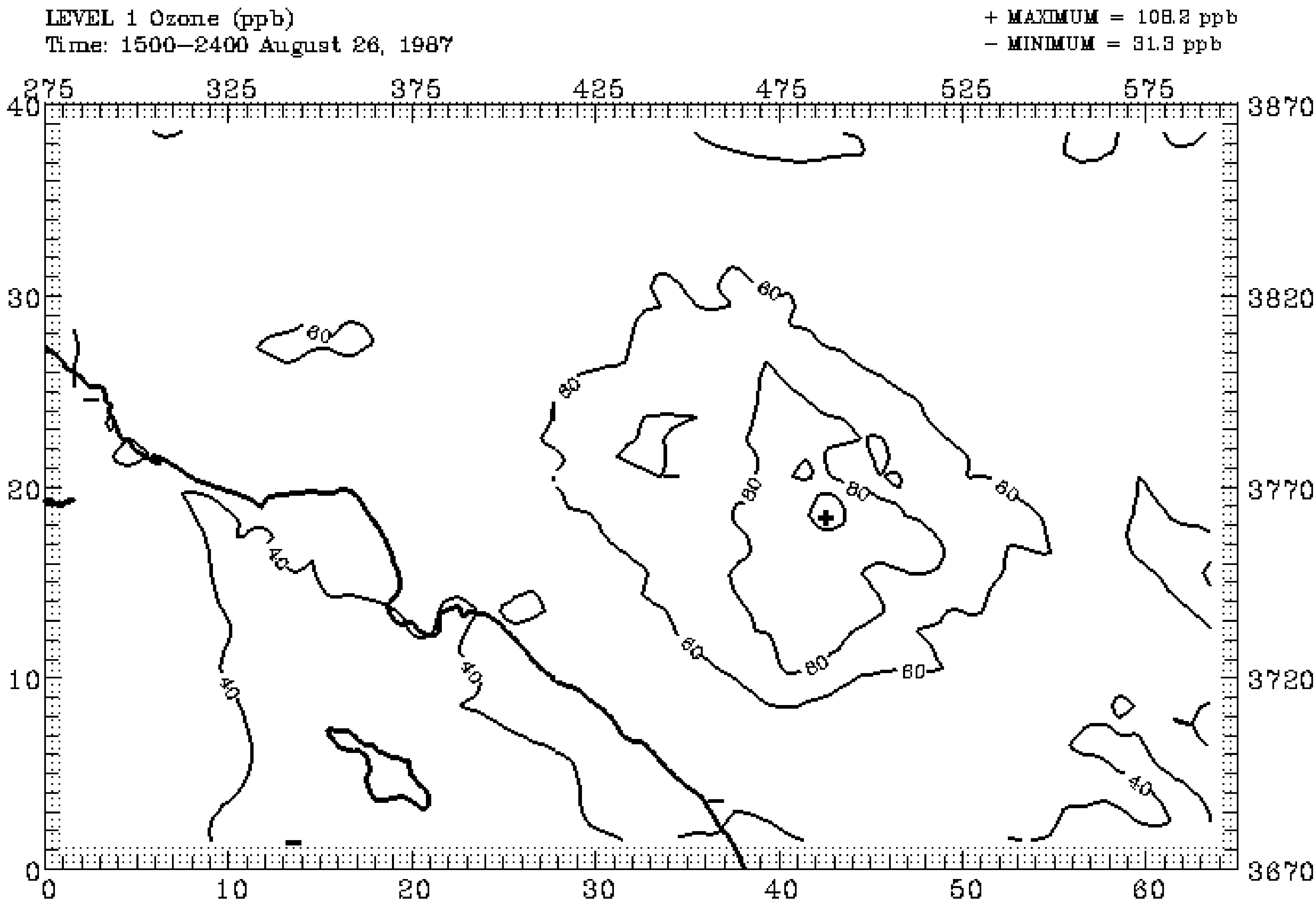


Figure 6a. Maximum simulated ozone concentrations for base year run with lowflux CB4 - August 26, 1987.

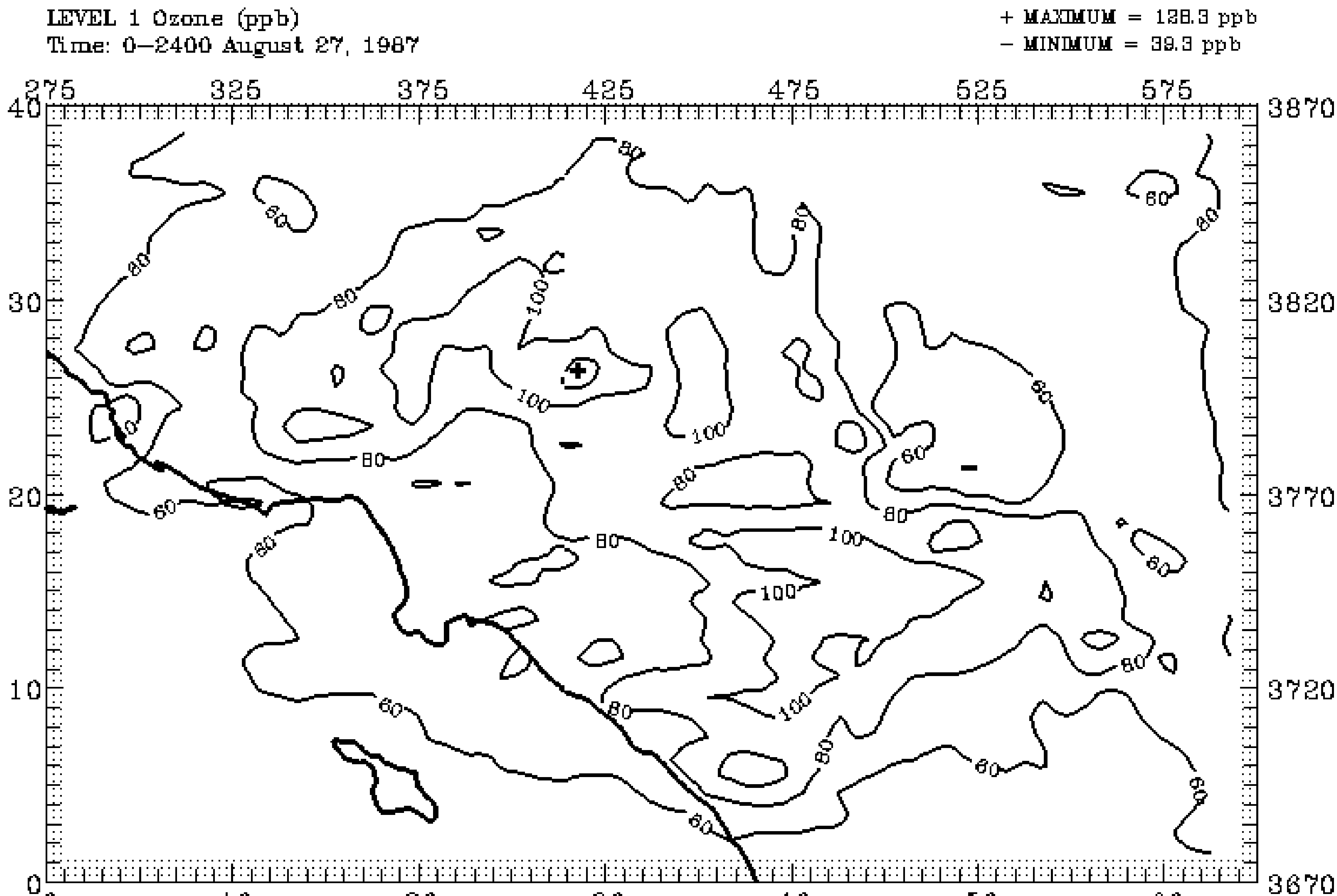


Figure 6b. Maximum simulated ozone concentrations for base year run with lowflux CB4 - August 27, 1987.

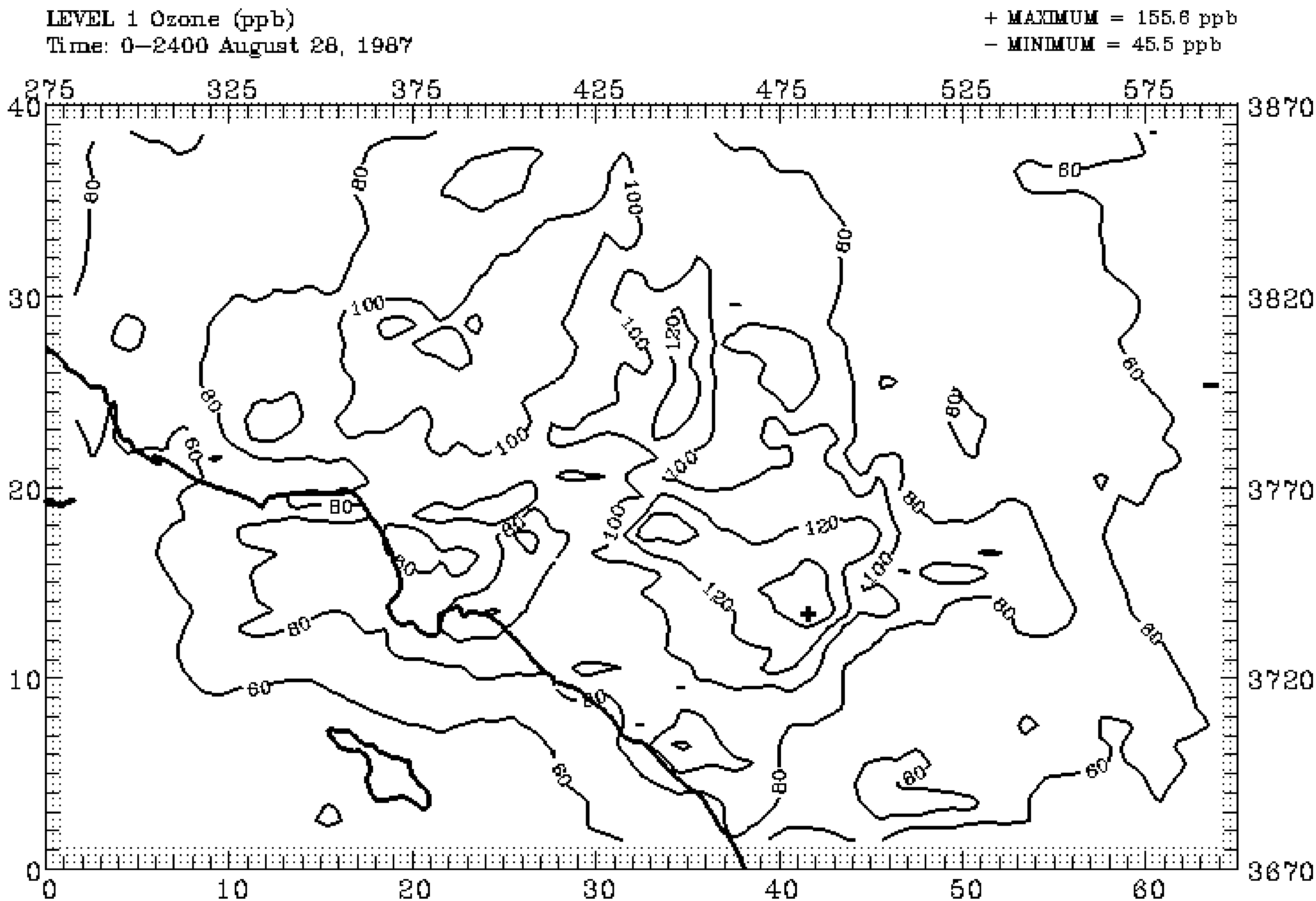


Figure 6c. Maximum simulated ozone concentrations for base year run with lowflux CB4 - August 28, 1987.

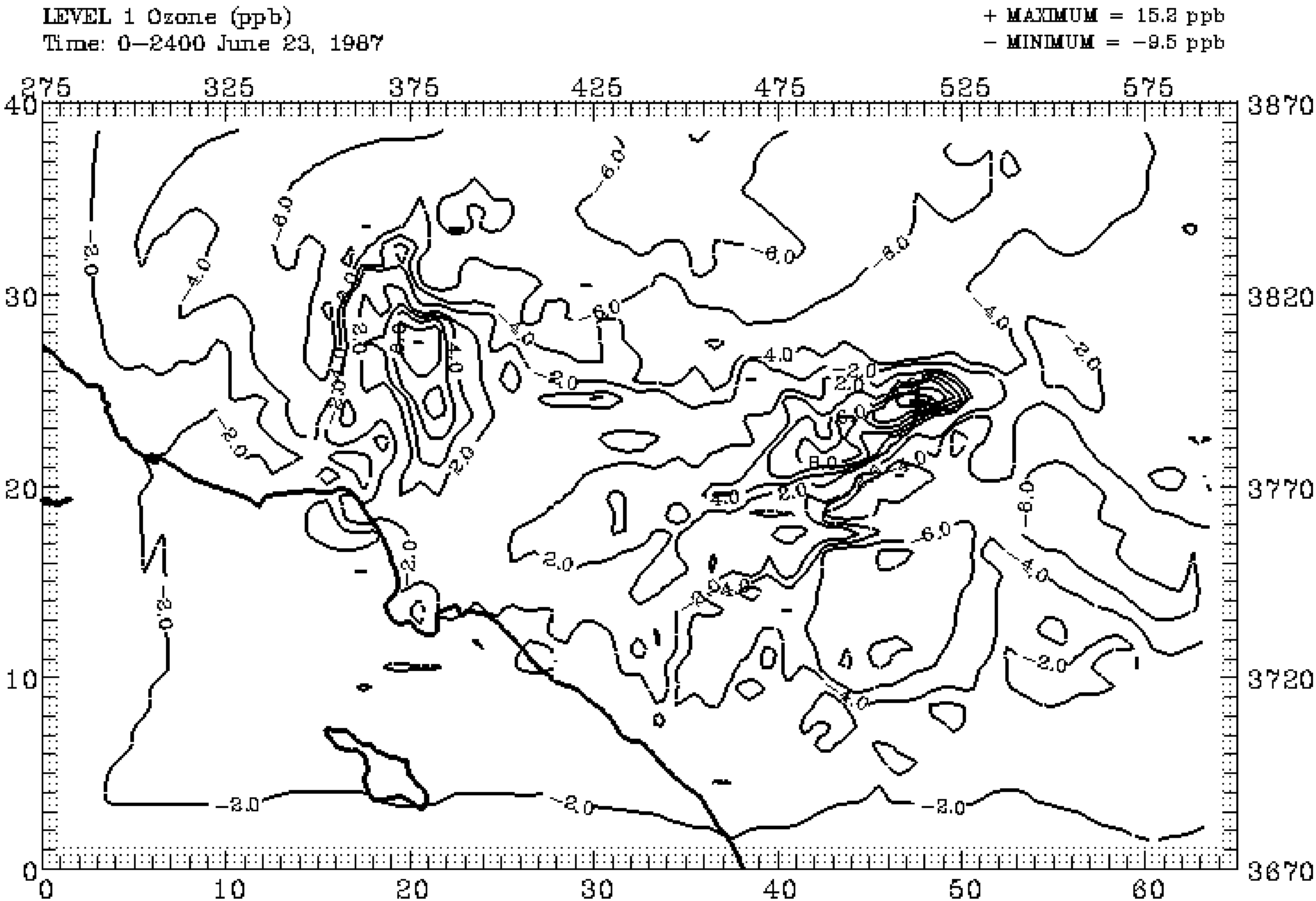
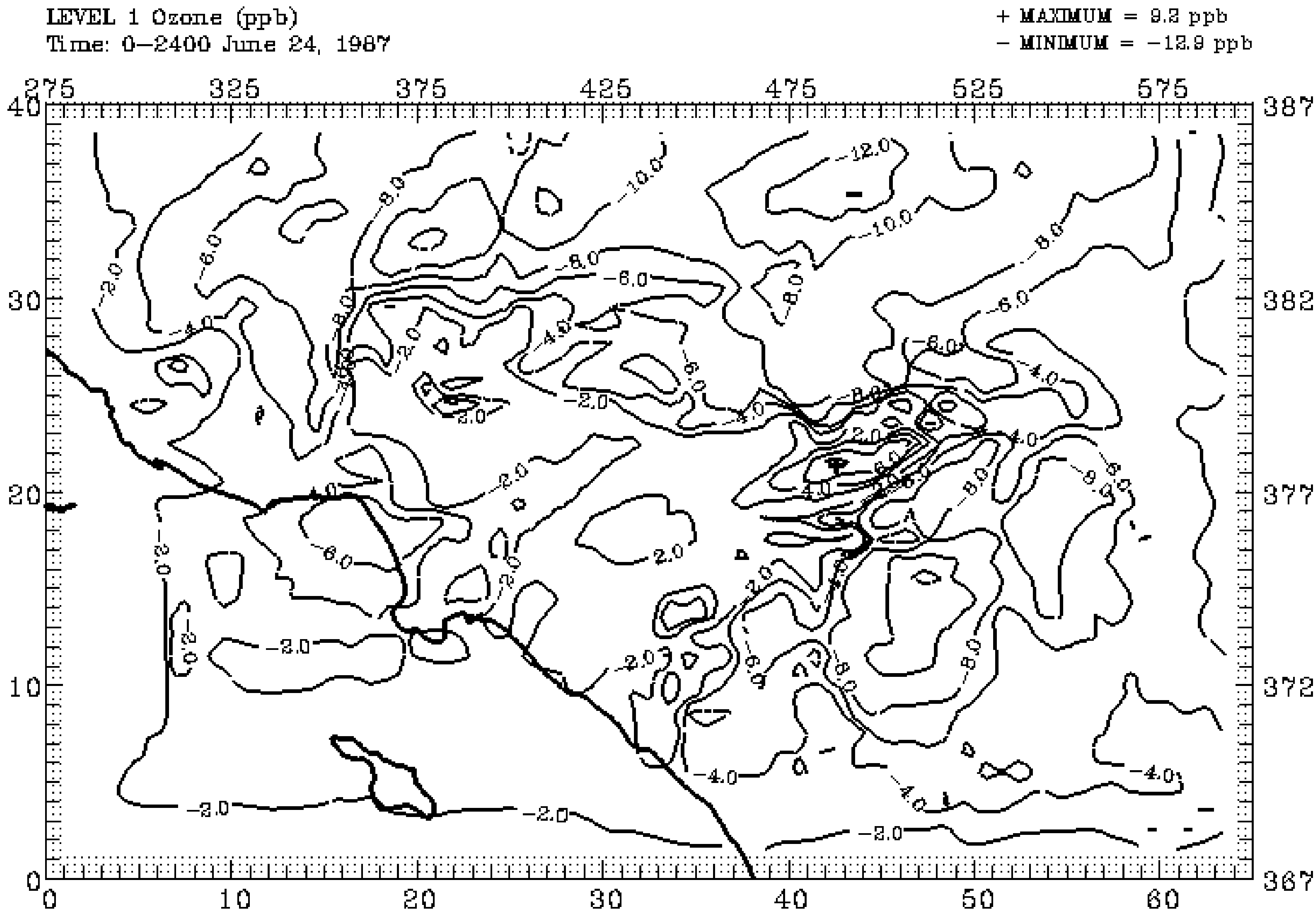


Figure 7a. Differences in maximum simulated ozone concentrations between highflux and stdcb4 base year run - June 23, 1987.



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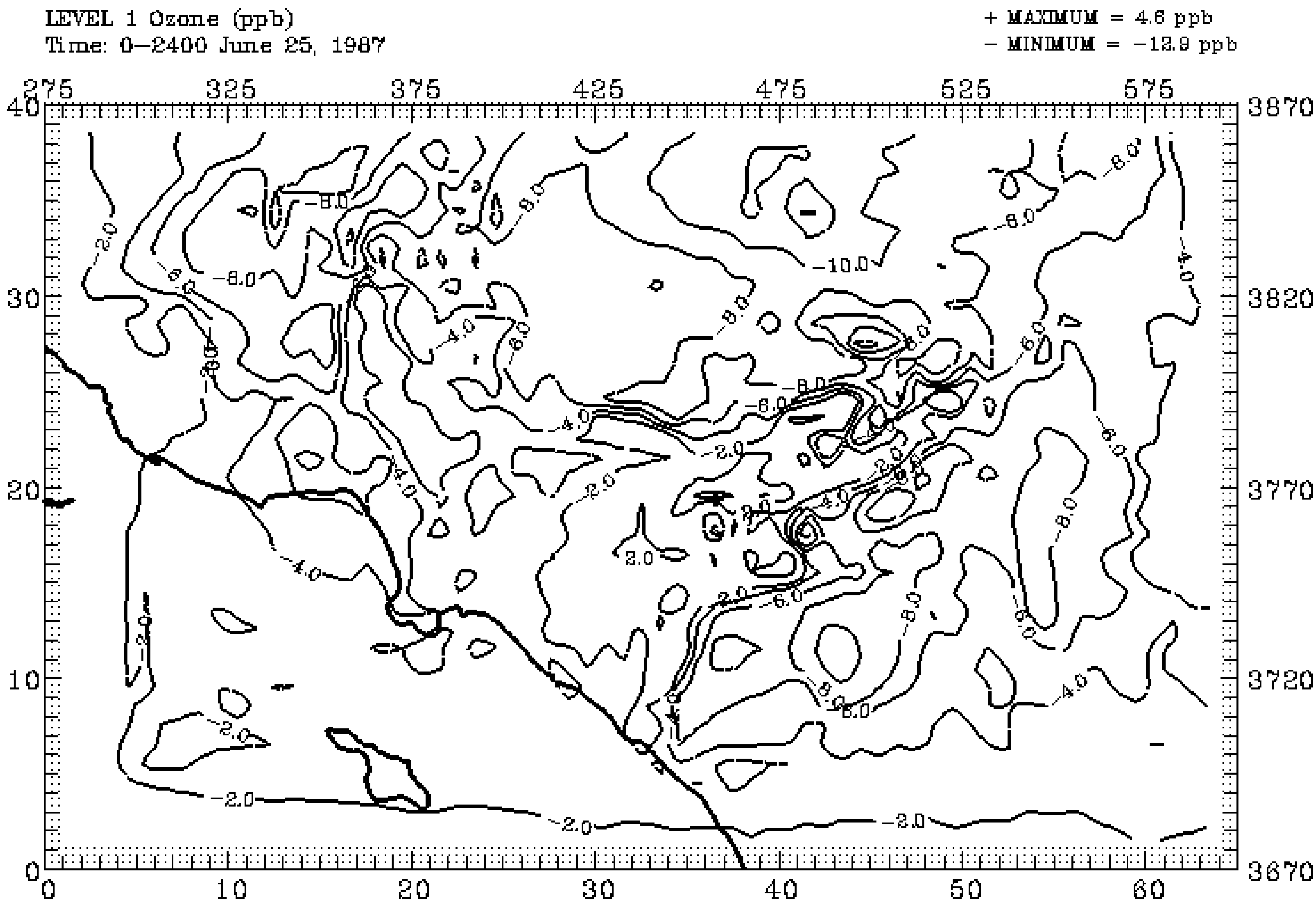


Figure 7c. Difference in maximum simulated ozone concentrations between highflux and stdcb4 base year run - June 25, 1987.

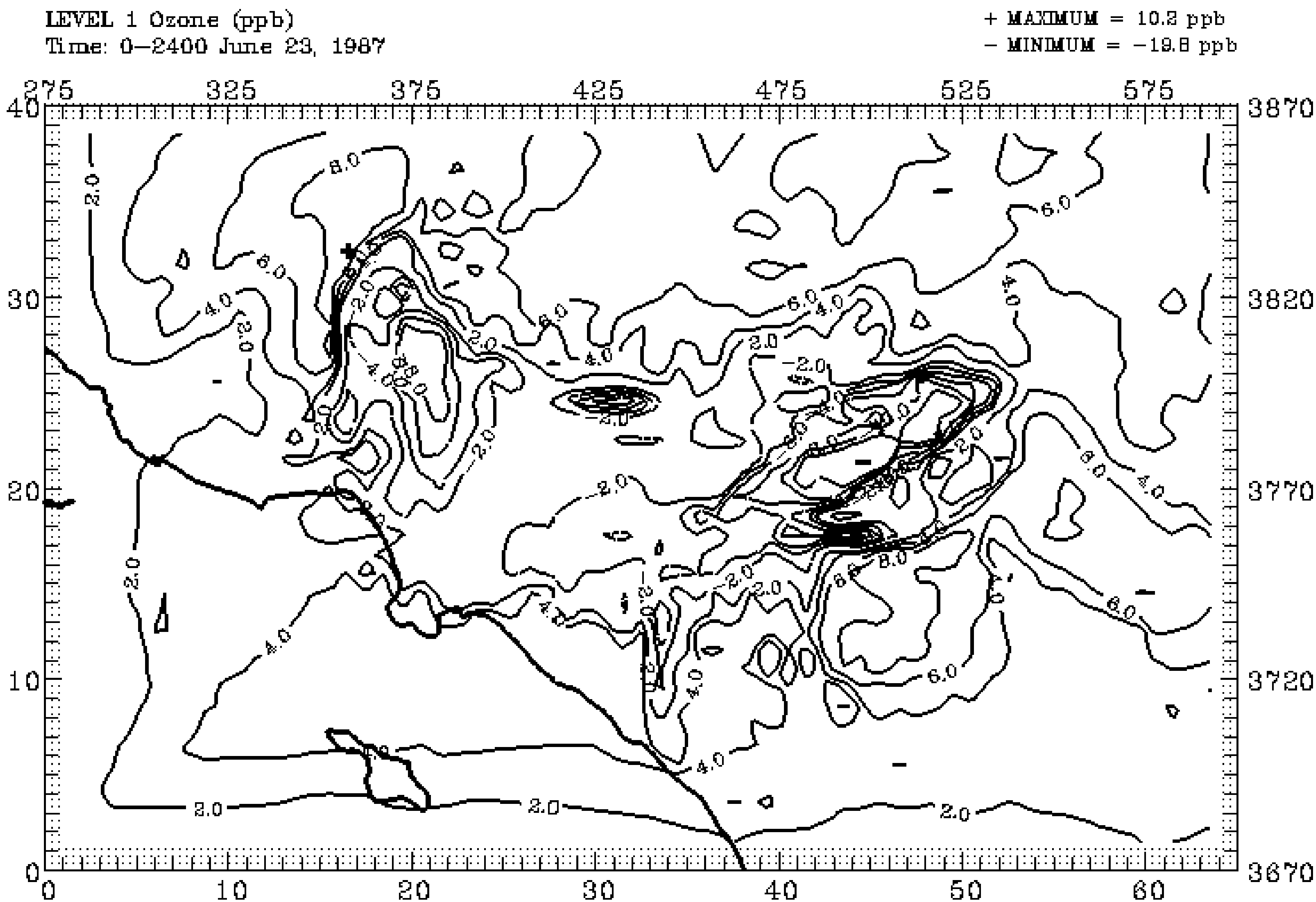
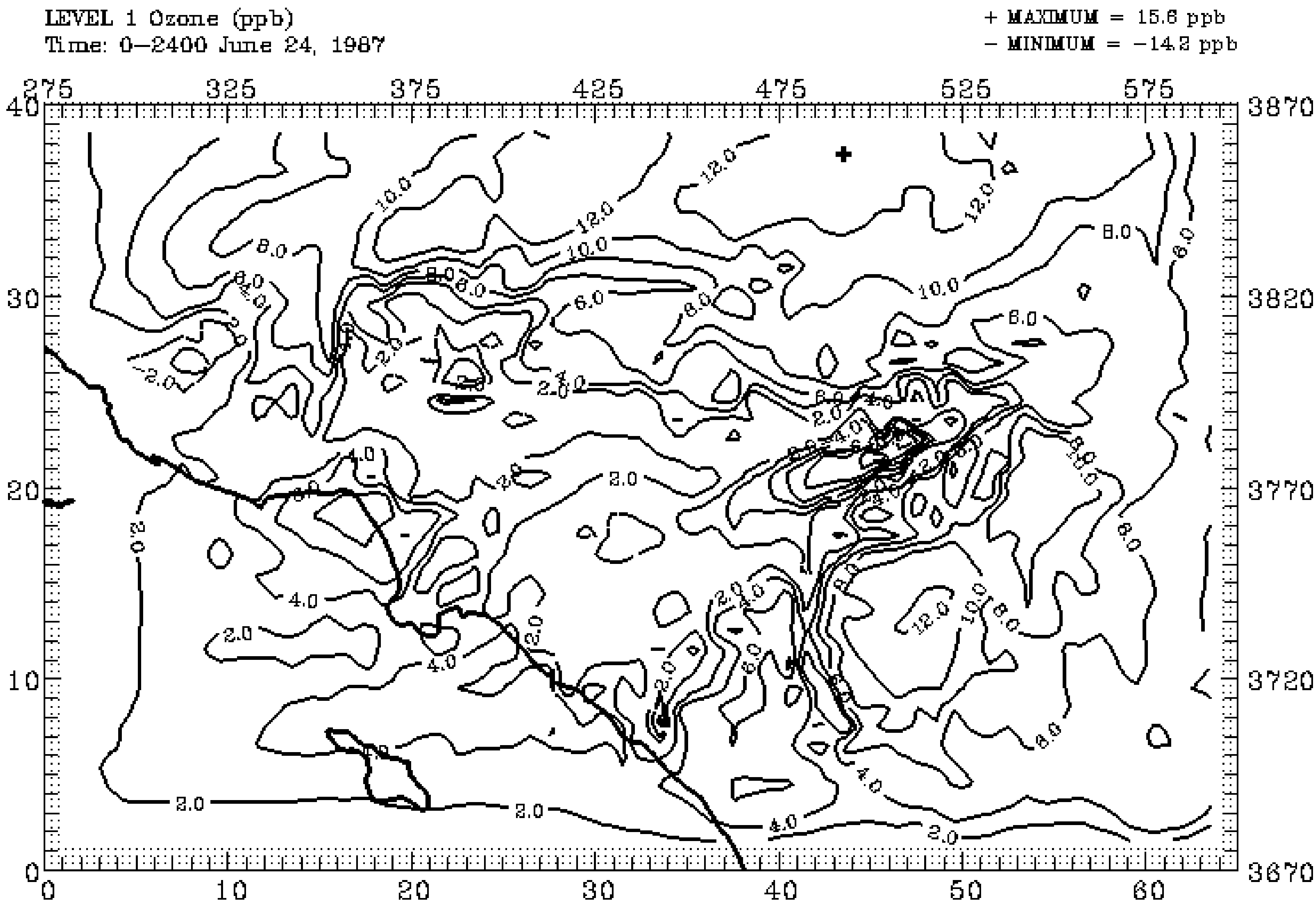


Figure 8a. Difference in maximum simulated ozone concentrations between lowflux and stdcb4 for base year run - June 23, 1987.



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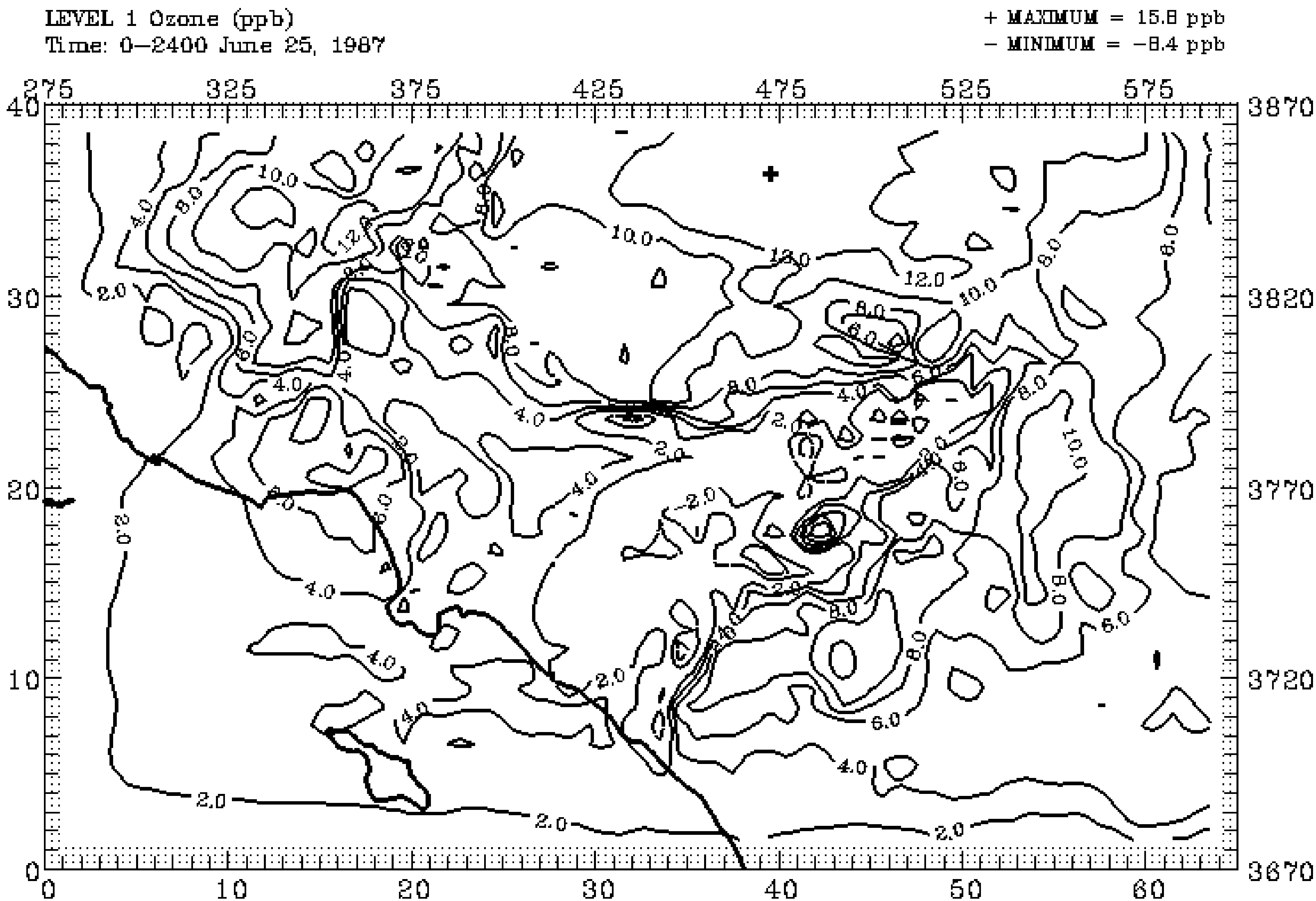


Figure 8c. Difference in maximum simulated ozone concentrations between lowflux and stdcb4 for base year run - June 25, 1987.

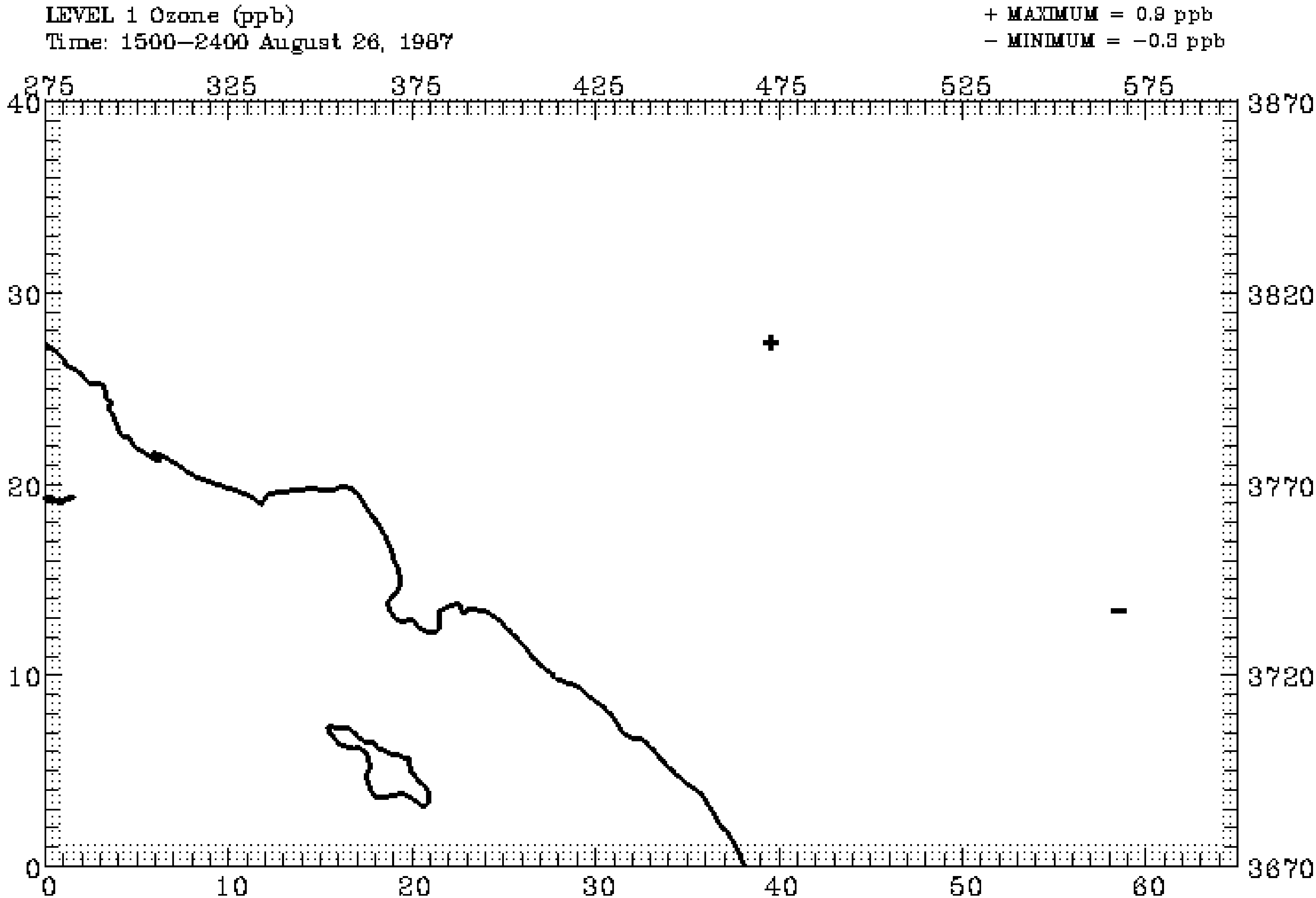


Figure 9a. Difference in maximum simulated ozone concentrations between highflux and stdcb4 for base year run - August 26, 1987.

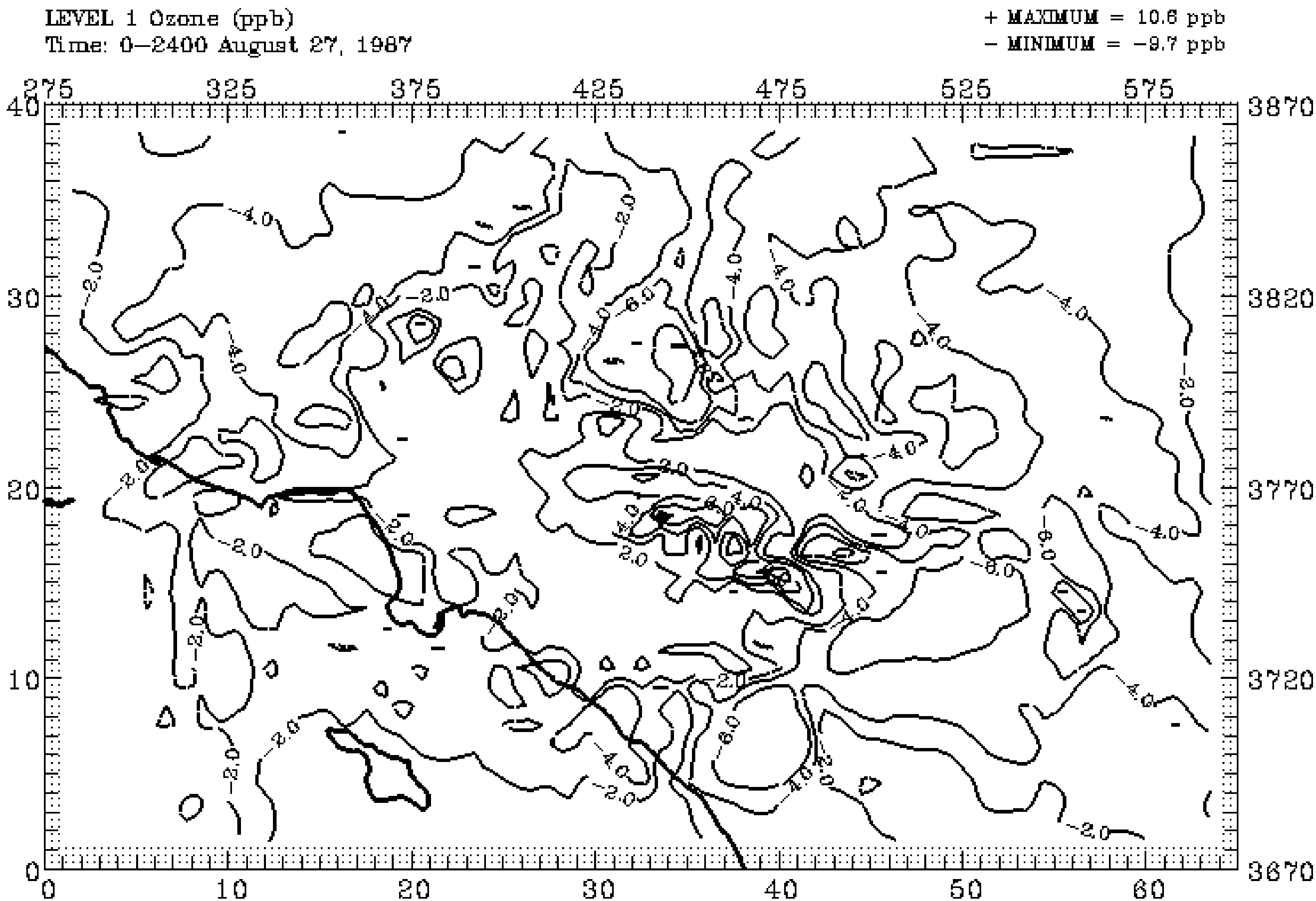


Figure 9b. Difference in maximum simulated ozone concentrations between highflux and stdcb4 for base year run - August 27, 1987.

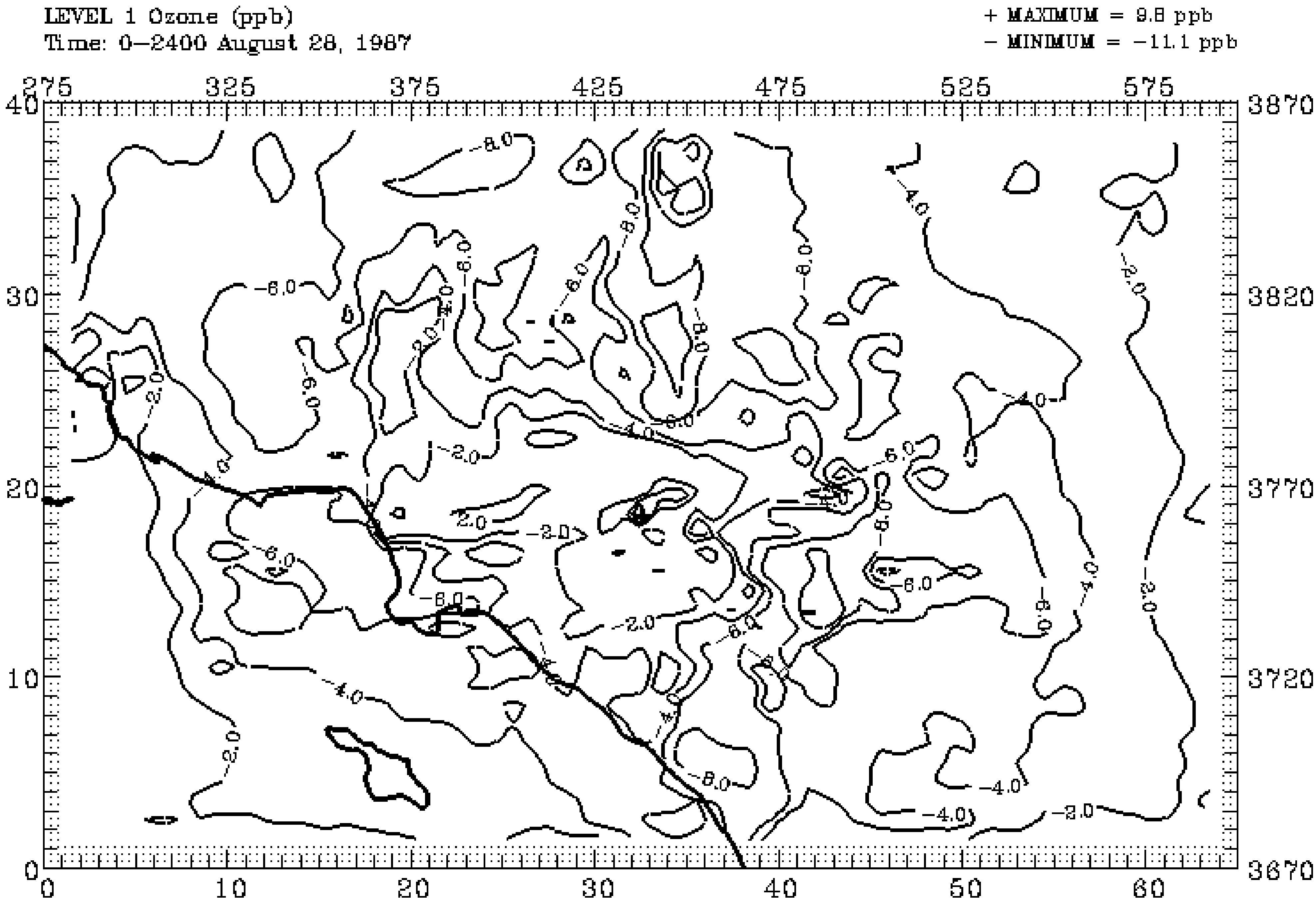


Figure 9c. Difference in maximum simulated ozone concentrations between highflux and stdcb4 for base year run - August 28, 1987.

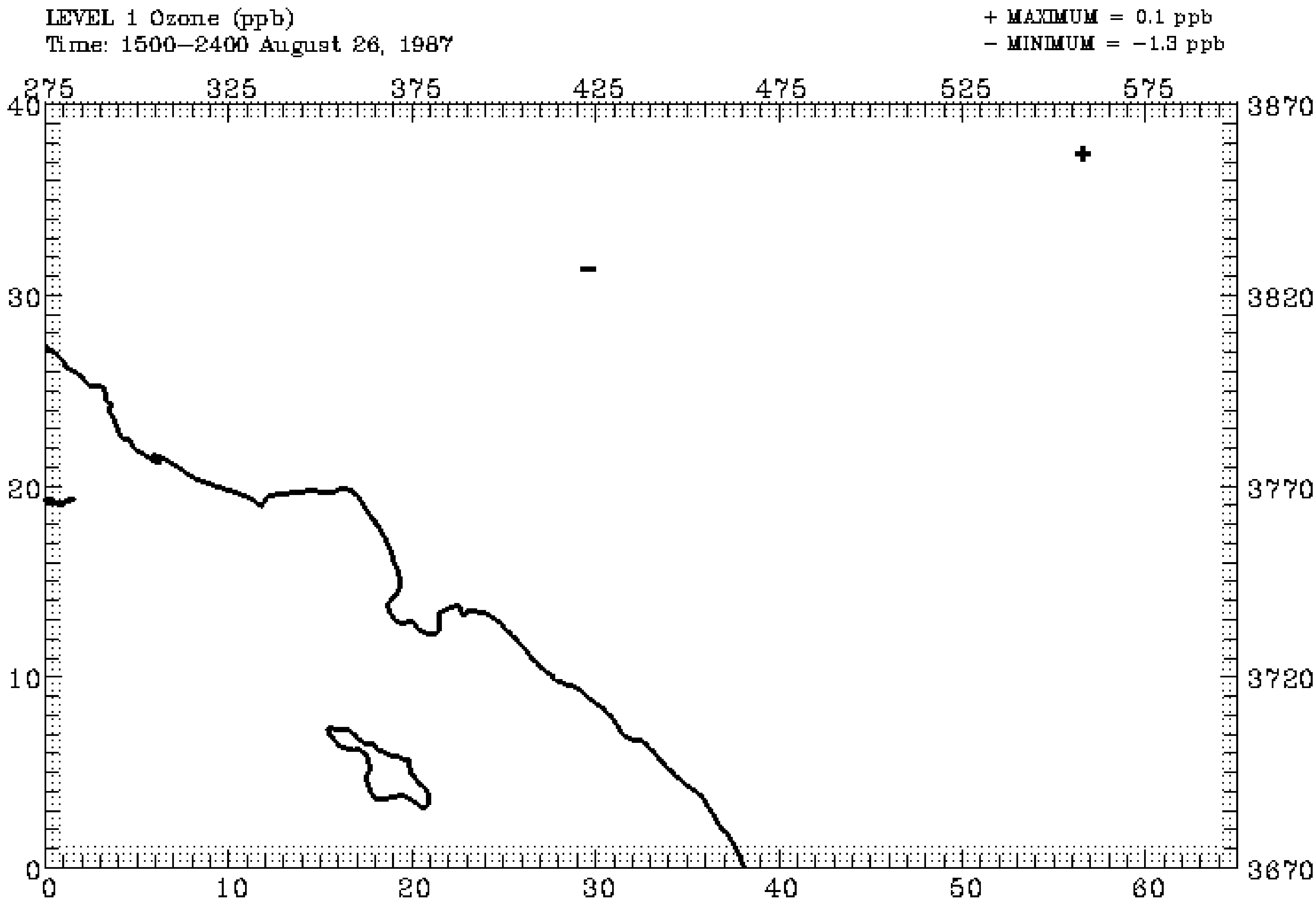
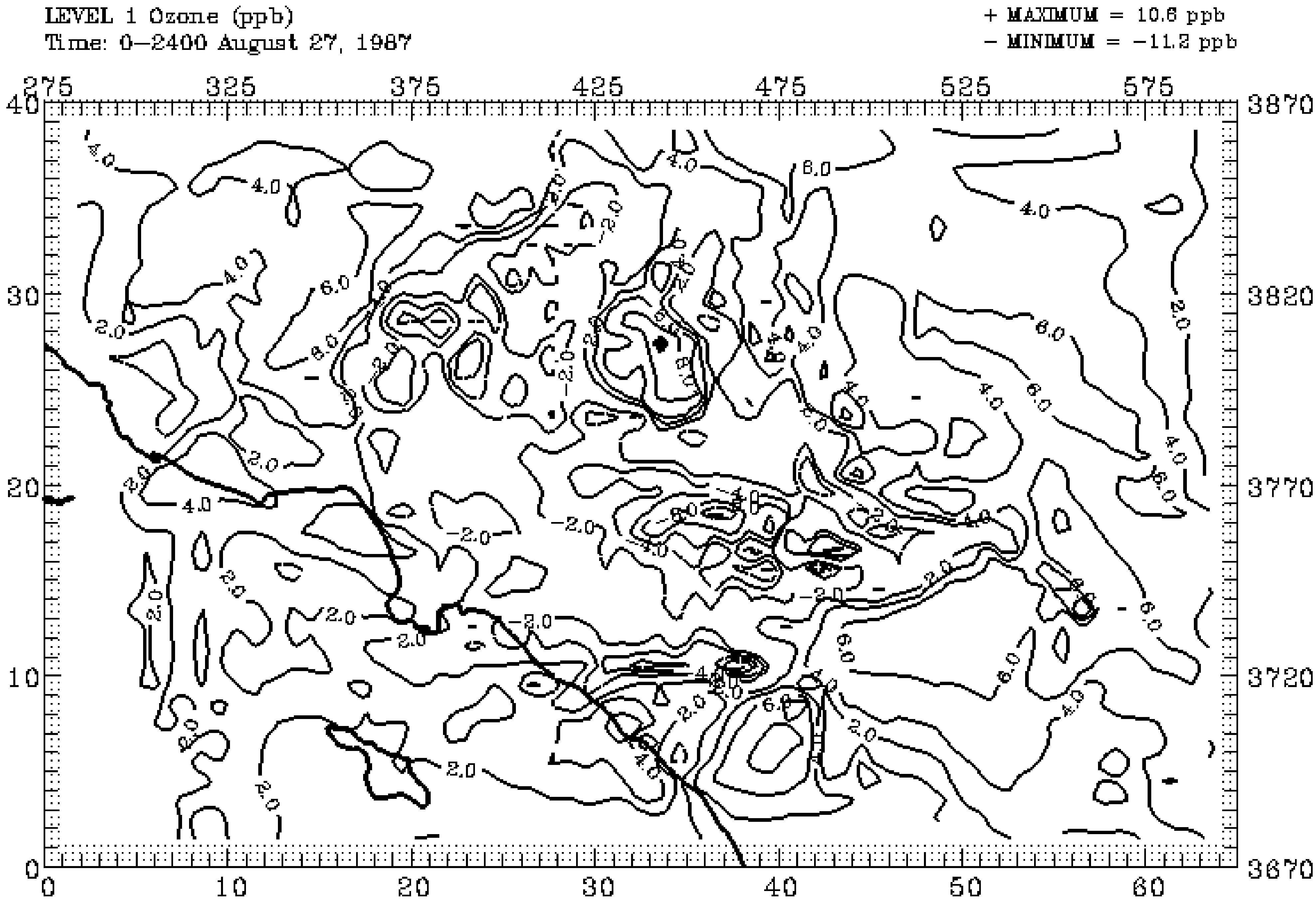


Figure 10a. Difference in maximum simulated ozone concentrations between lowflux and stdcb4 for base year run - August 26, 1987.



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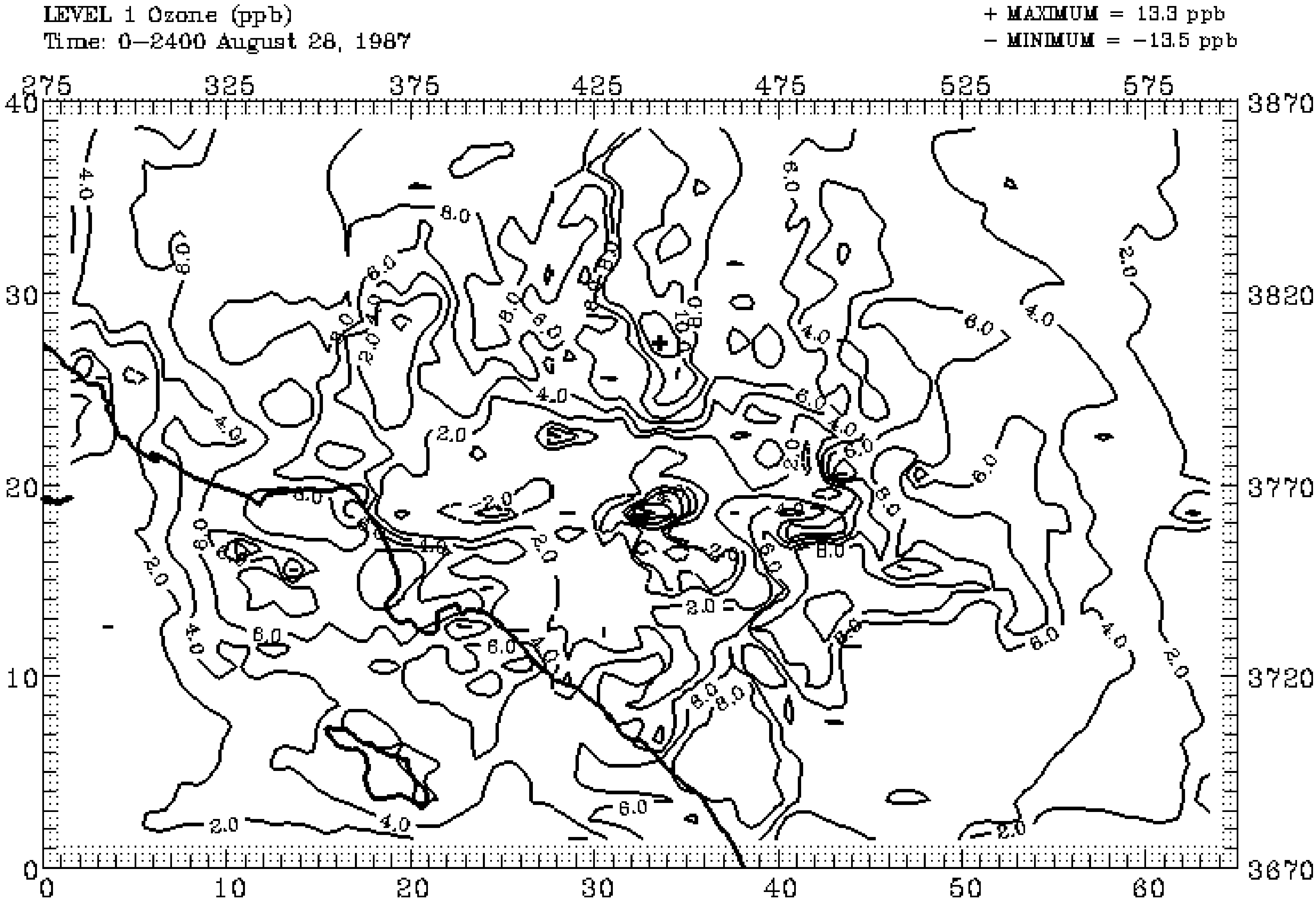


Figure 10c. Difference in maximum simulated ozone concentrations between lowflux and stdcb4 for base year run - August 28, 1987.

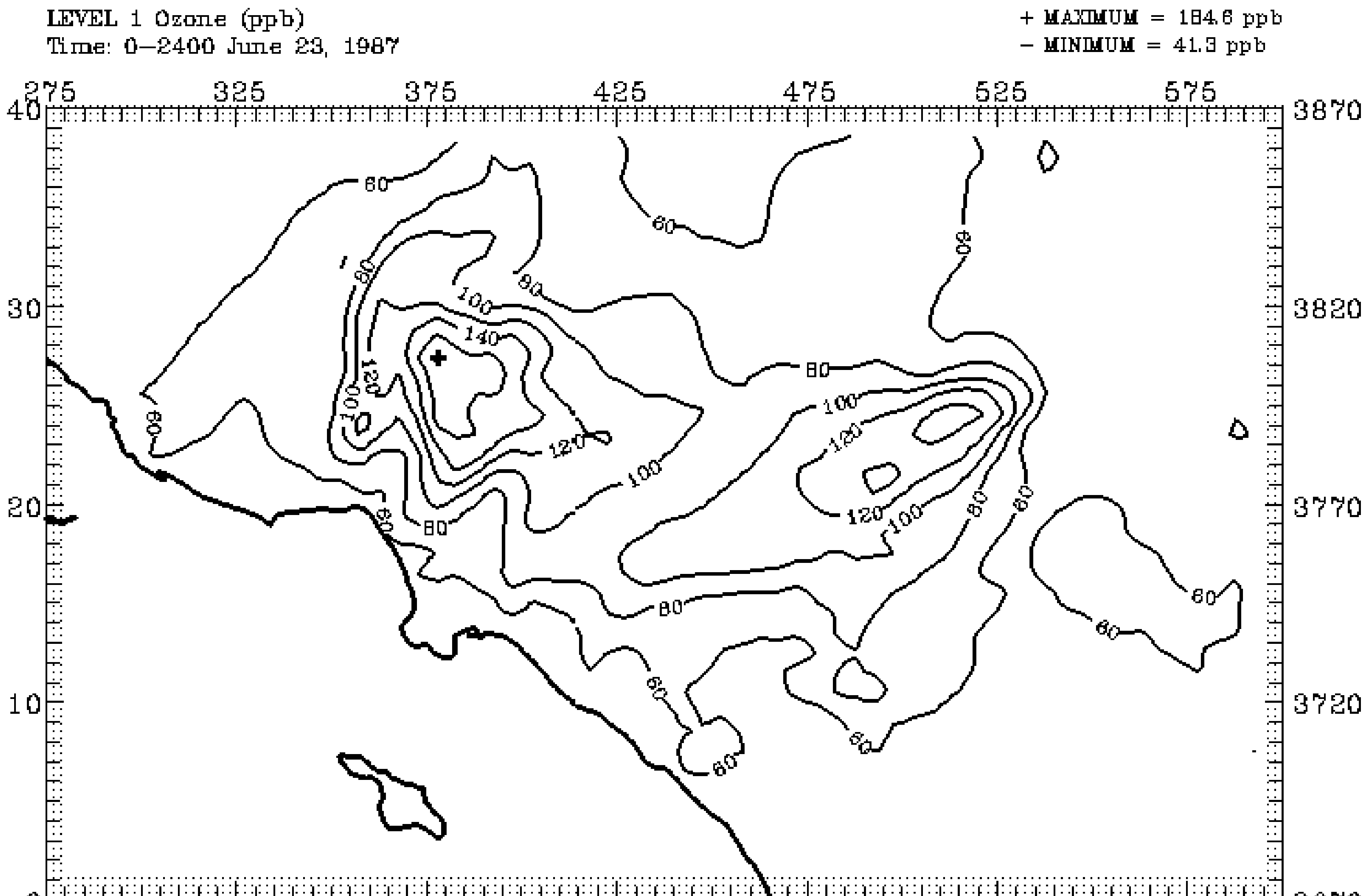


Figure 11a. Maximum simulated ozone concentrations for 50% NOx reduction with standard CB4 - June 23, 1987.

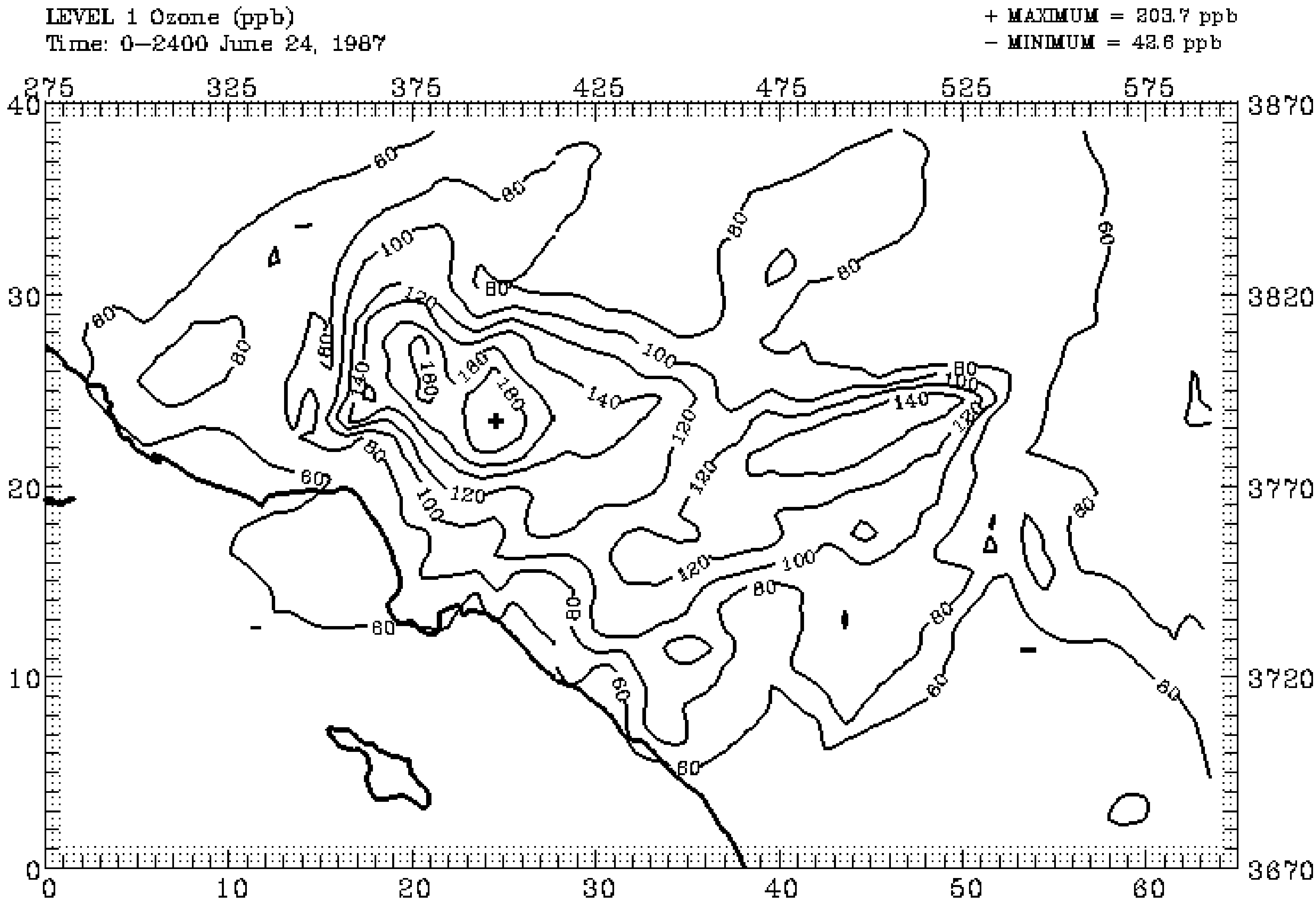


Figure 11b. Maximum simulated ozone concentrations for 50% NOx reduction with standard CB4 - June 24, 1987.

LEVEL 1 Ozone (ppb)
Time: 0–2400 June 25, 1987

+ MAXIMUM = 192.3 ppb
– MINIMUM = 41.4 ppb

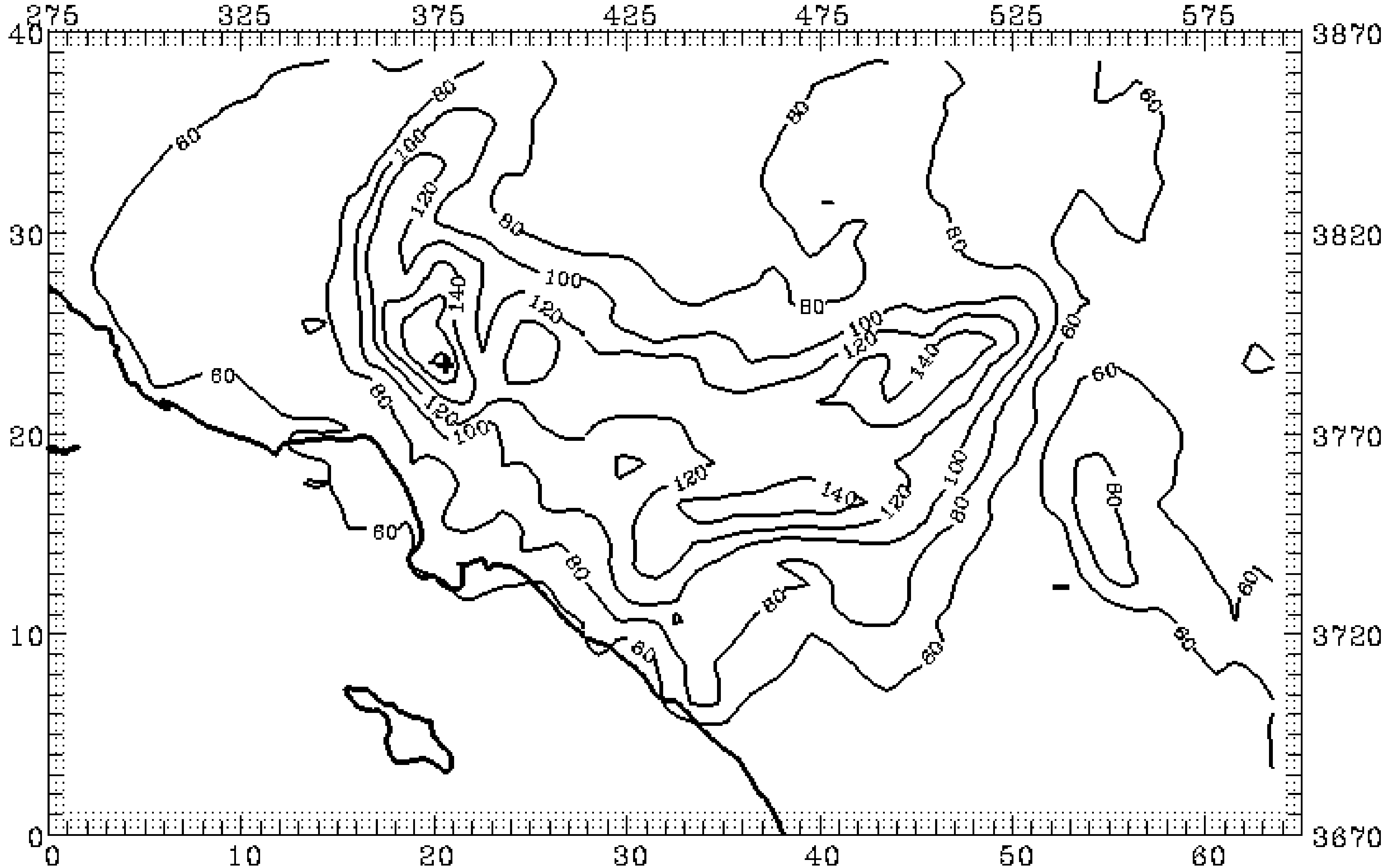


Figure 11c. Maximum simulated ozone concentrations for 50% NOx reduction with standard CB4 - June 25, 1987.

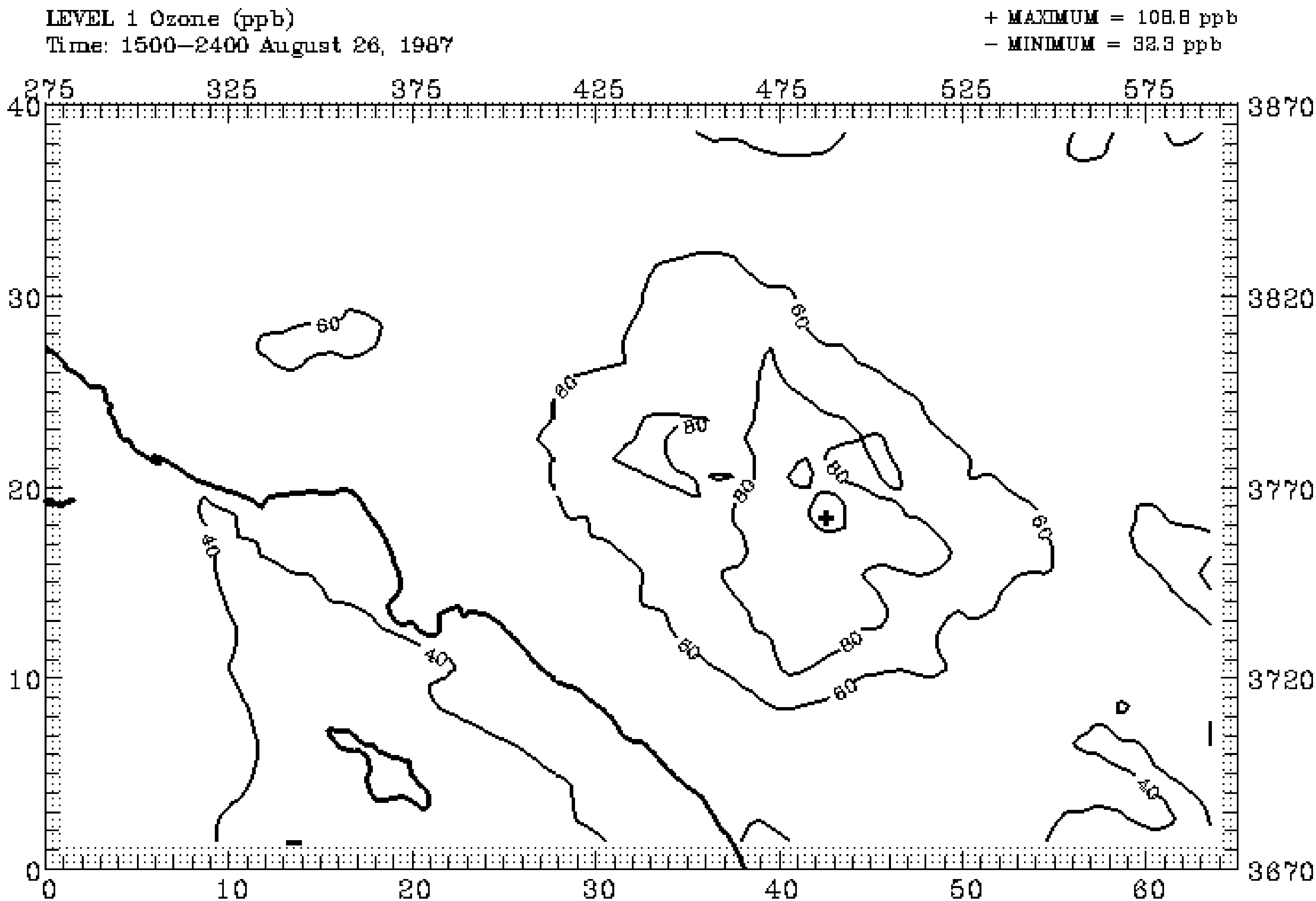


Figure 12a. Maximum simulated ozone concentrations for 50% NOx reduction with standard CB4 - August 26, 1987.

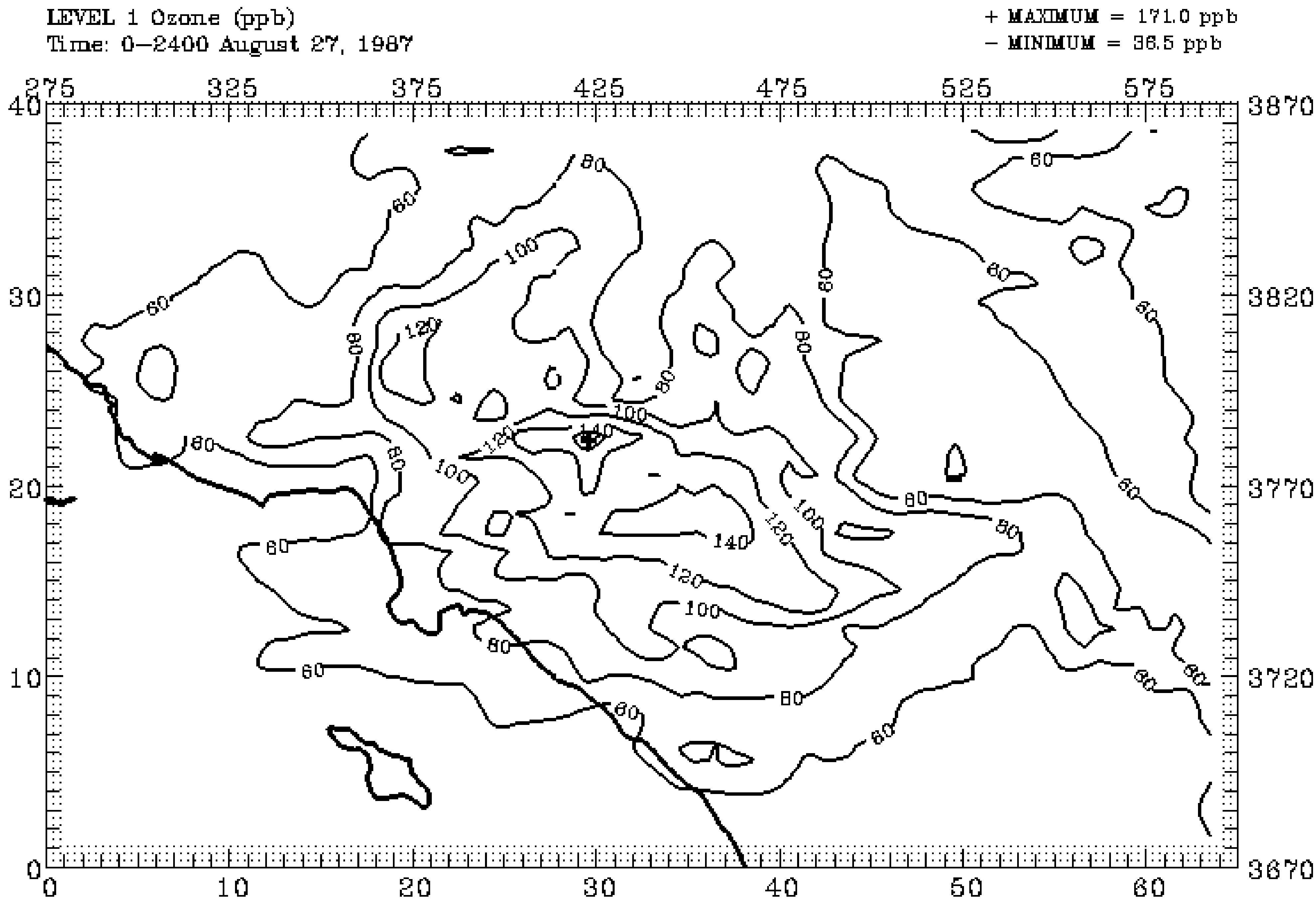


Figure 12b. Maximum simulated ozone concentrations for 50% NOx reduction with standard CB4 - August 27, 1987.

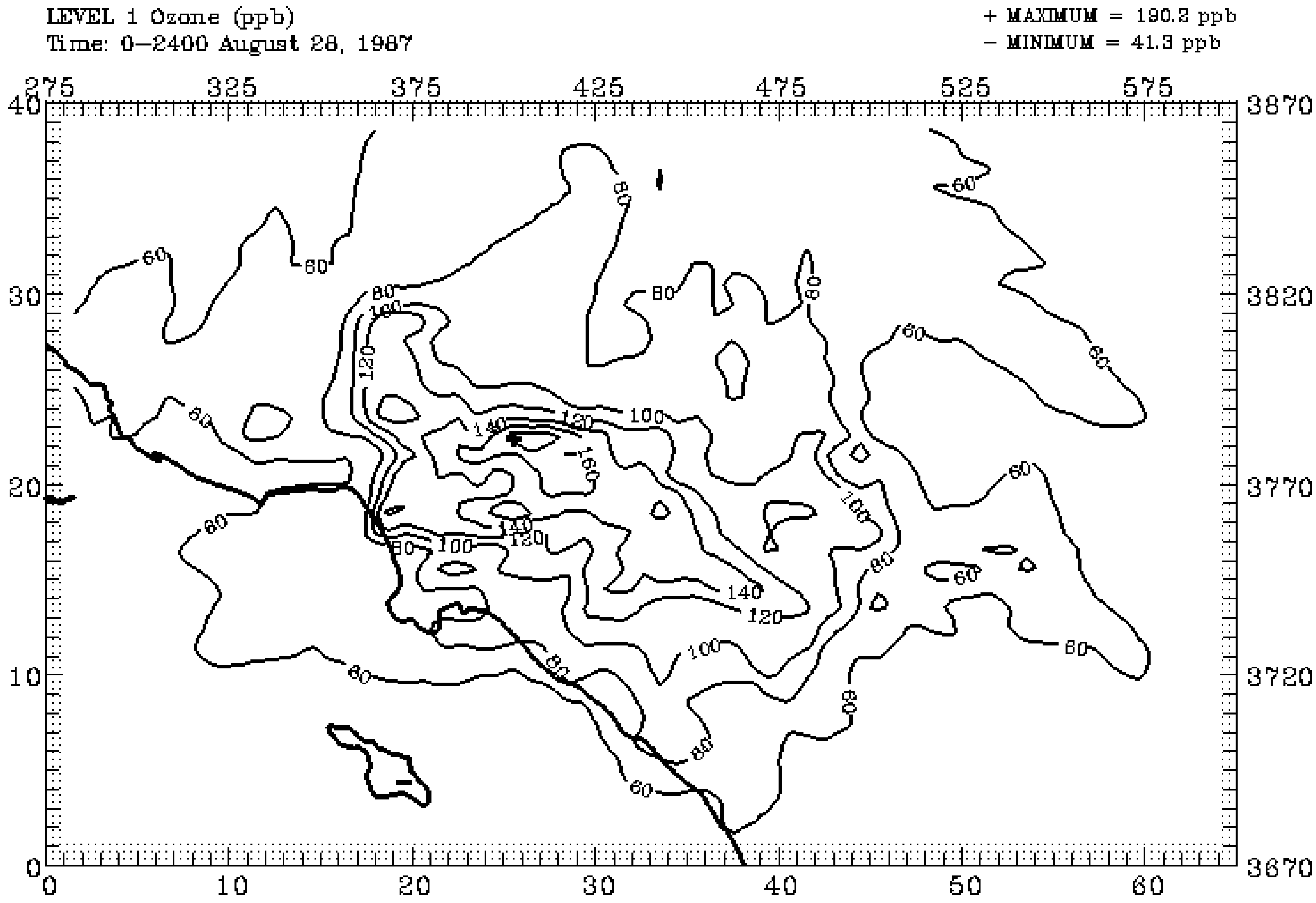


Figure 12c. Maximum simulated ozone concentrations for 50% NOx reduction with standard CB4 - August 28, 1987.

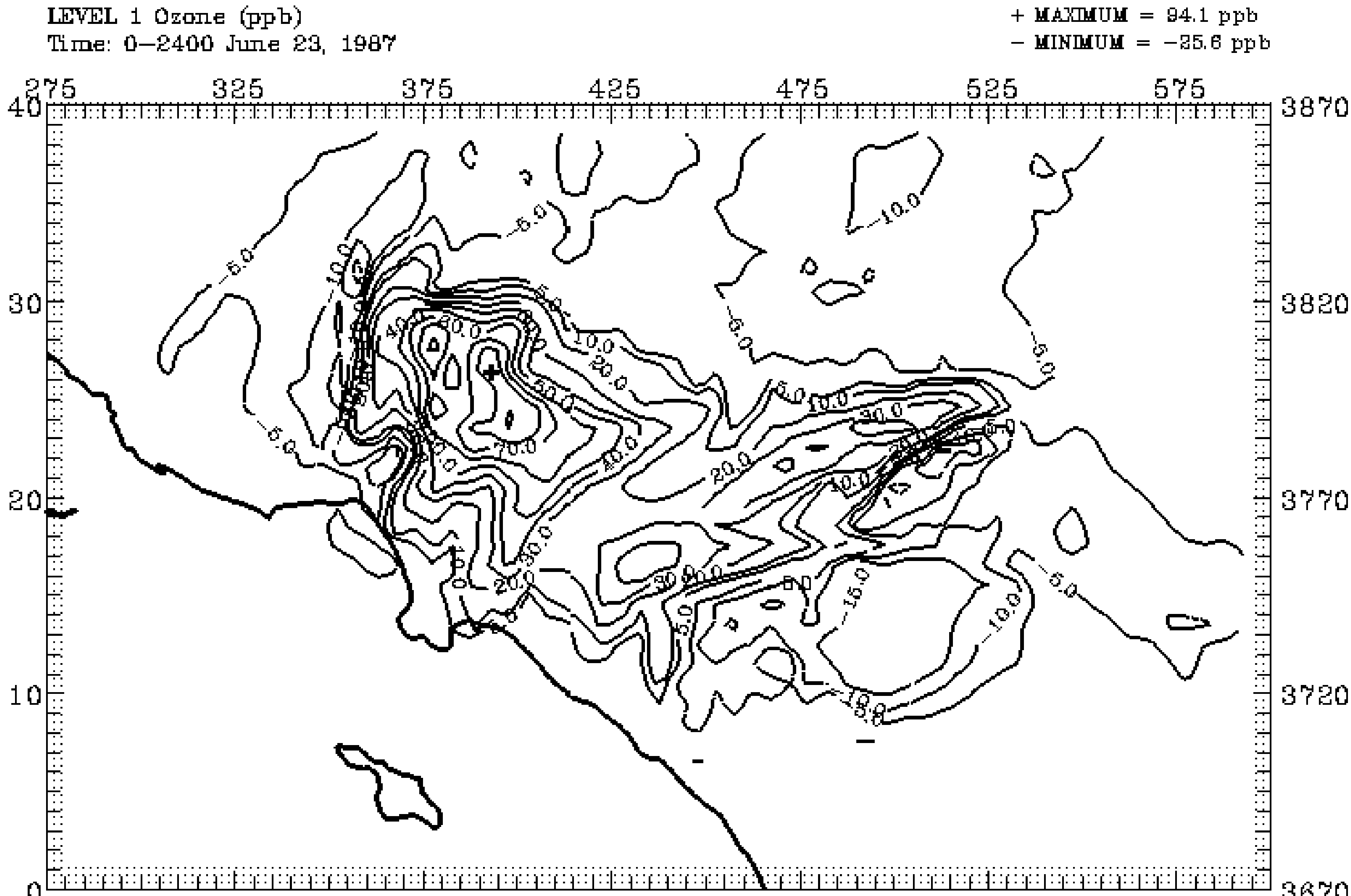


Figure 13a. Difference in maximum simulated ozone concentrations between NOx control run and base year run with standard CB4 - June 23, 1987.

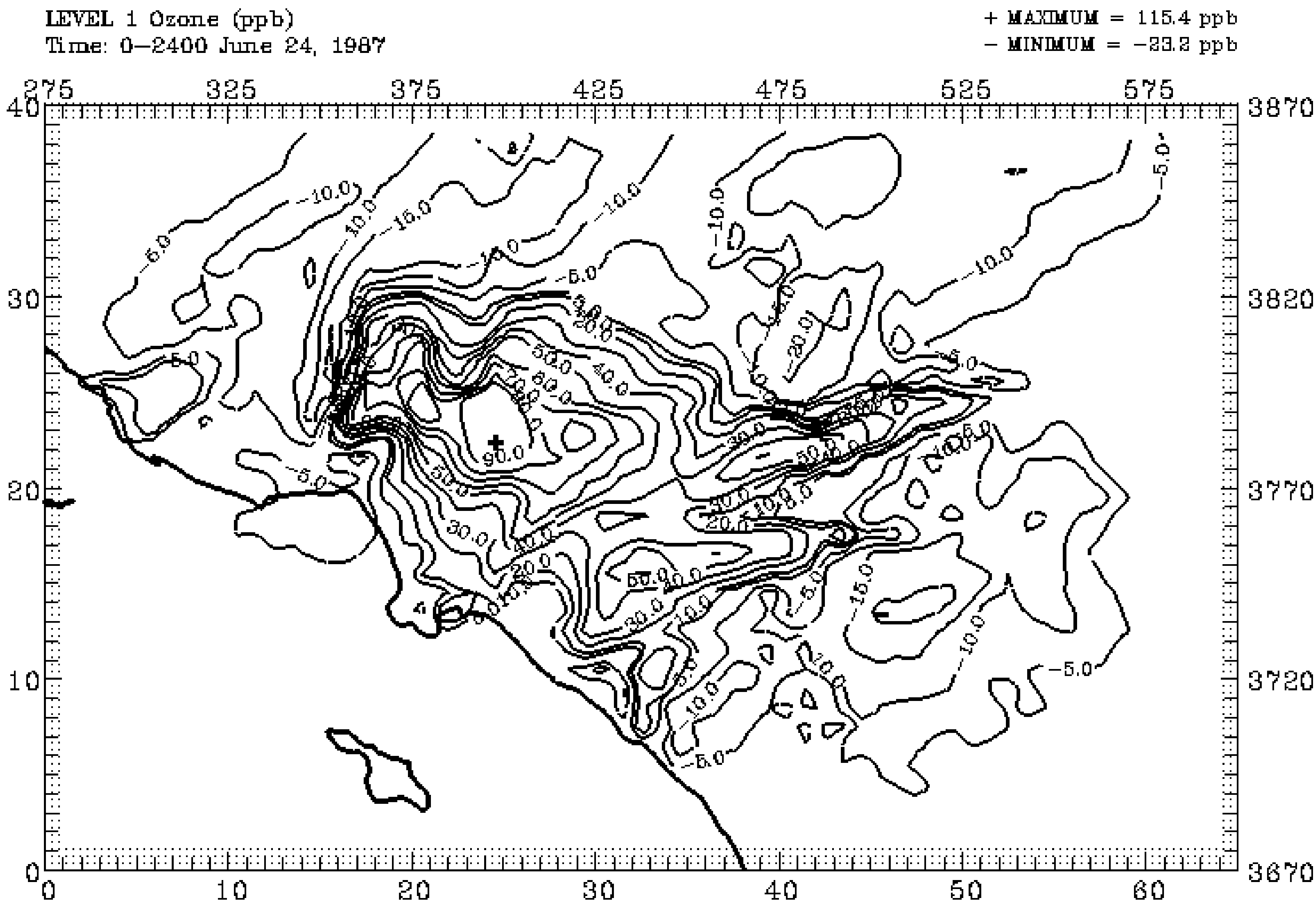


Figure 13b. Difference in maximum simulated ozone concentrations between NOx control run and base year run with standard CB4 - June 24, 1987.

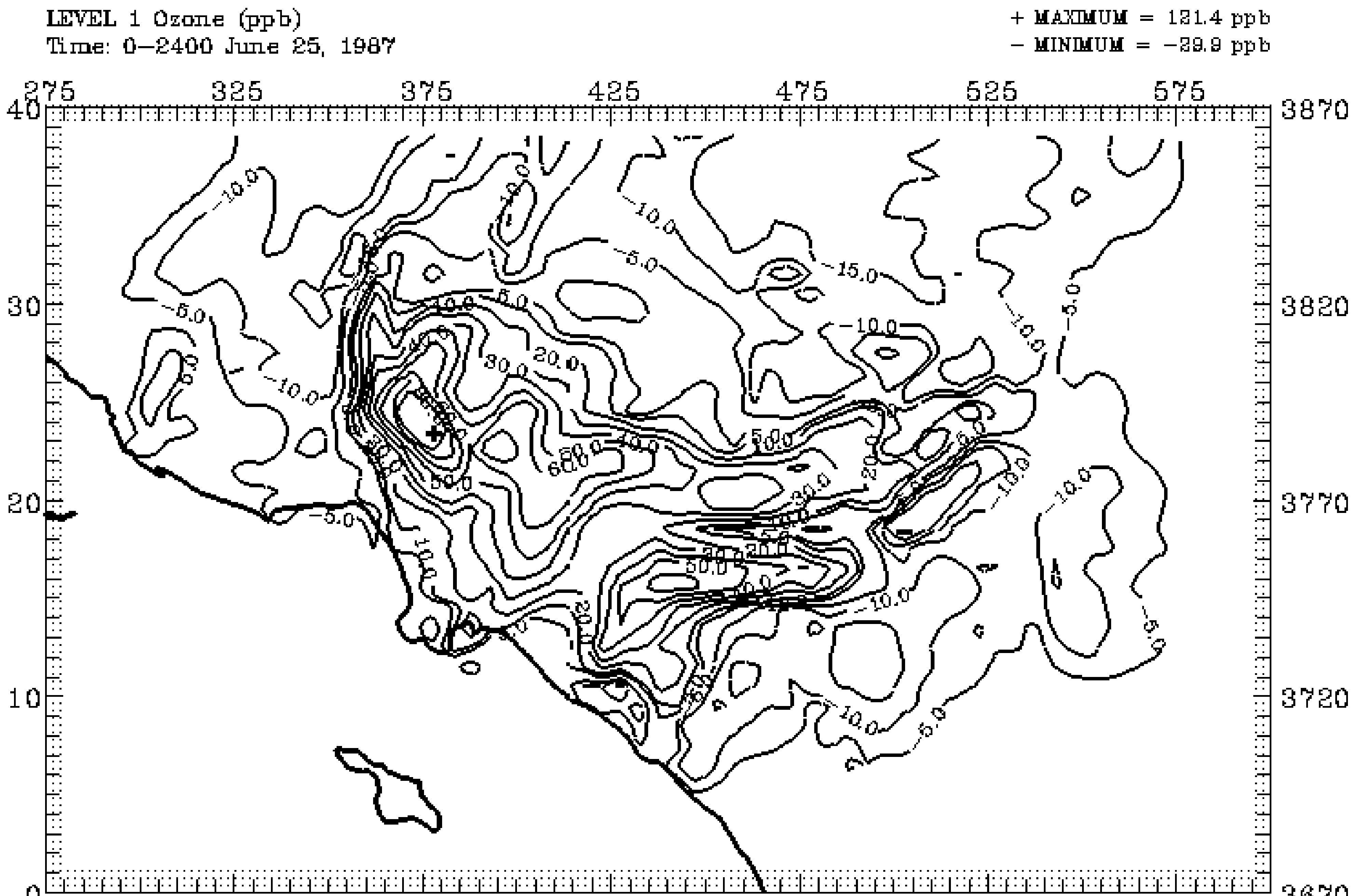


Figure 13c. Difference in maximum simulated ozone concentrations between NOx control rum and base year run with standard CB4 - June 25, 1987.

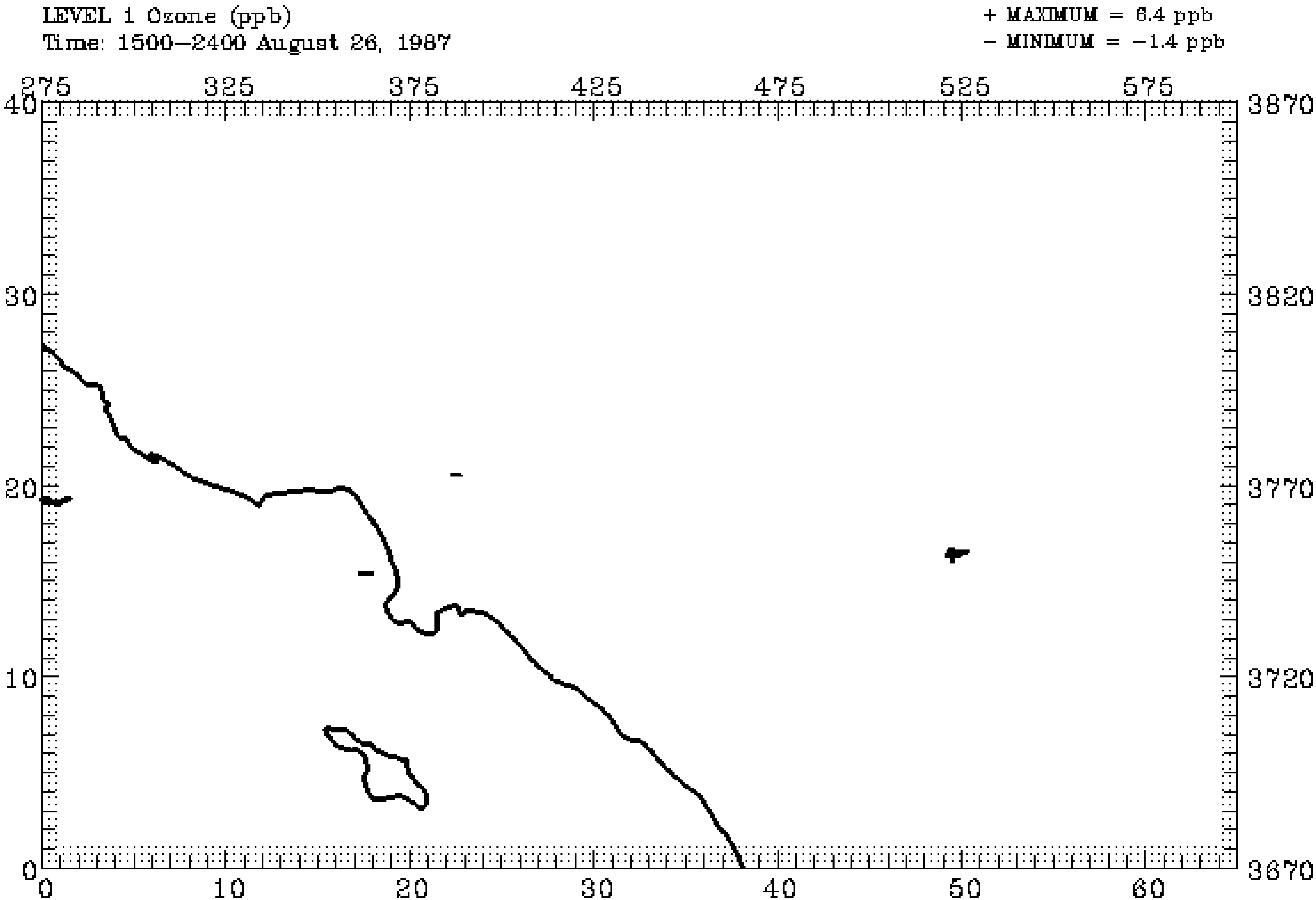


Figure 14a. Difference in maximum simulated ozone concentrations between NOx control run and base year run with standard CB4 - August 26, 1987.

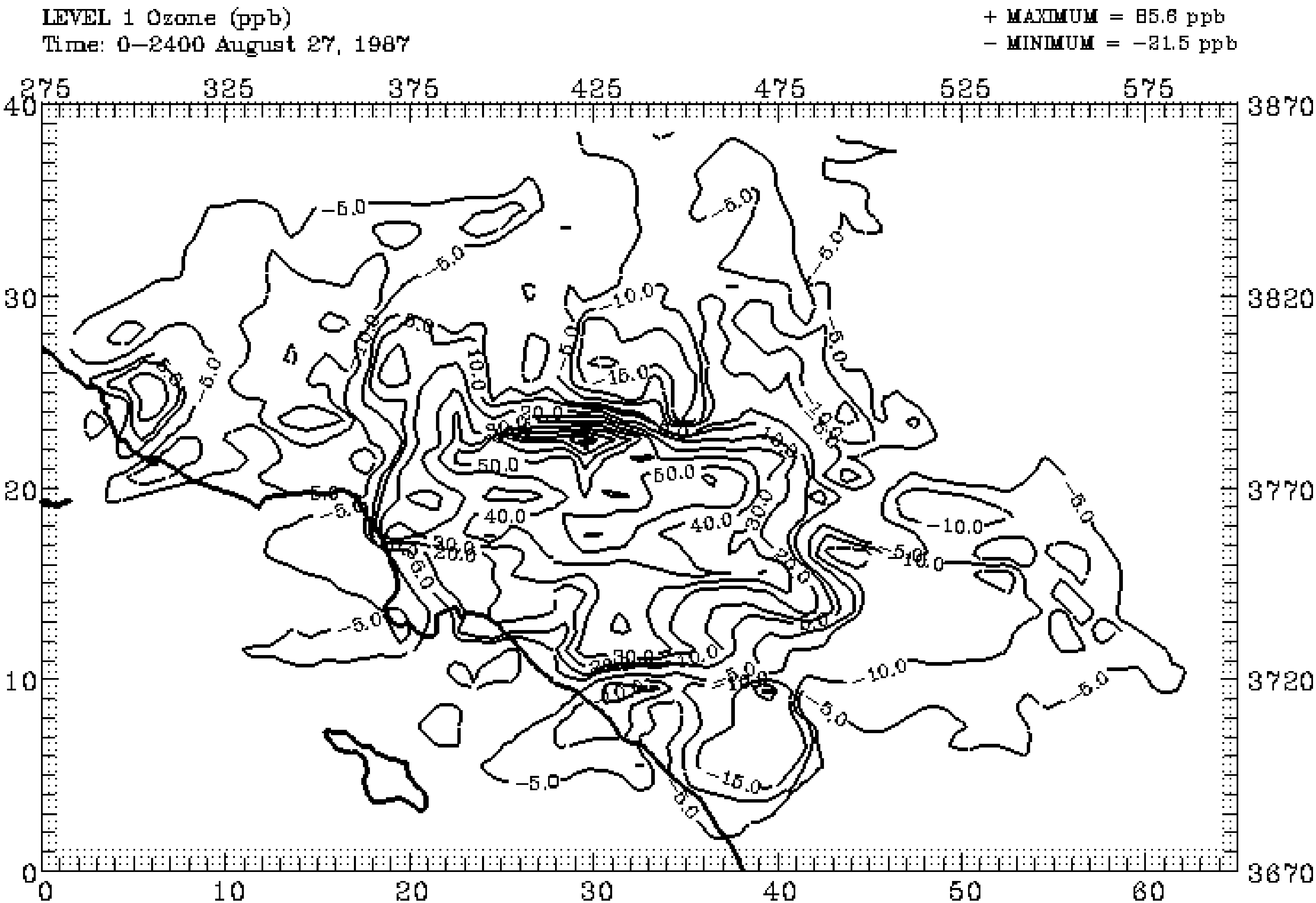


Figure 14b. Difference in maximum simulated ozone concentrations between NOx control run and base year run with standard CB4 - August 27, 1987.

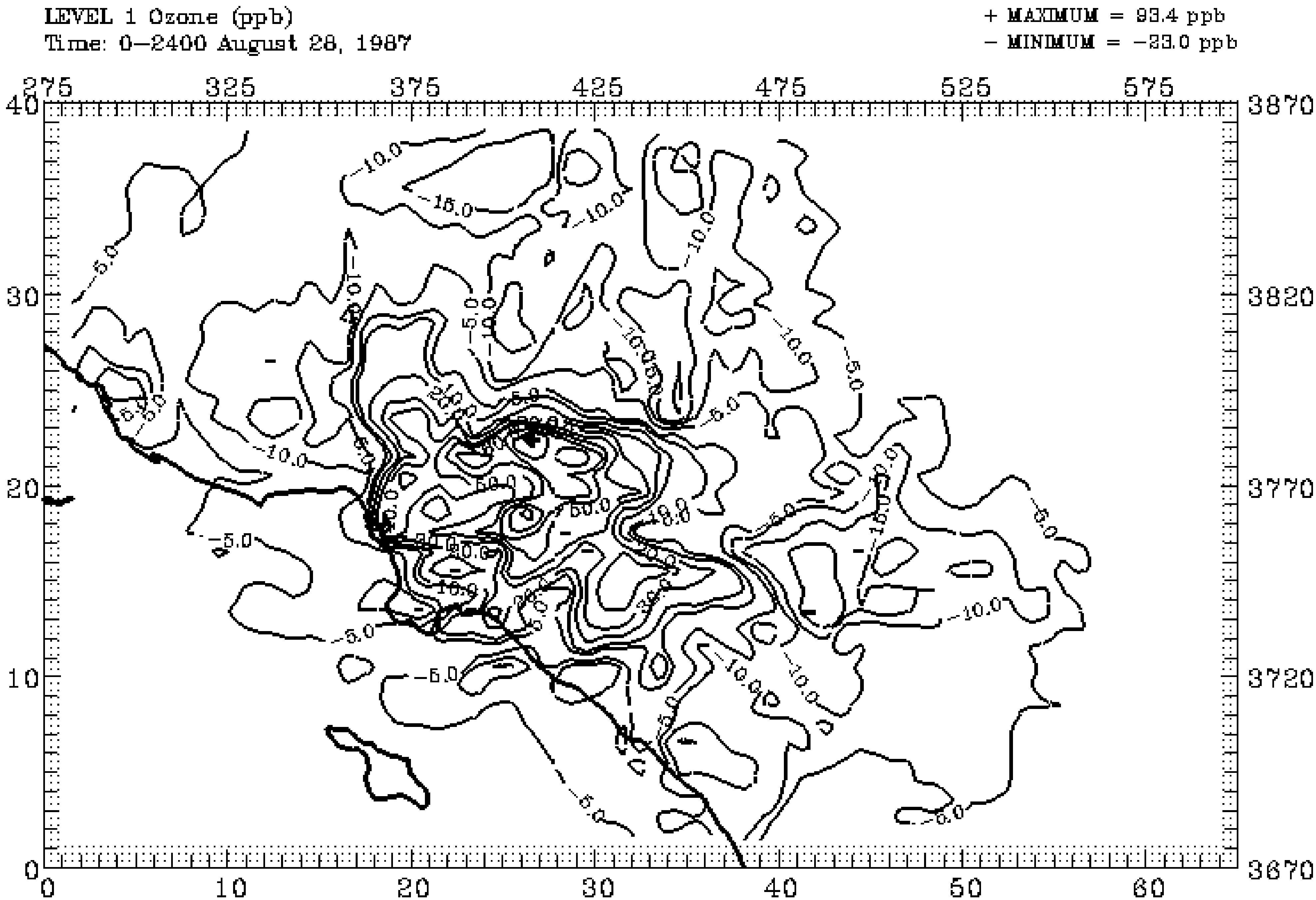


Figure 14c. Difference in maximum simulated ozone concentrations between NOx control run and base year run with standard CB4 - August 28, 1987.

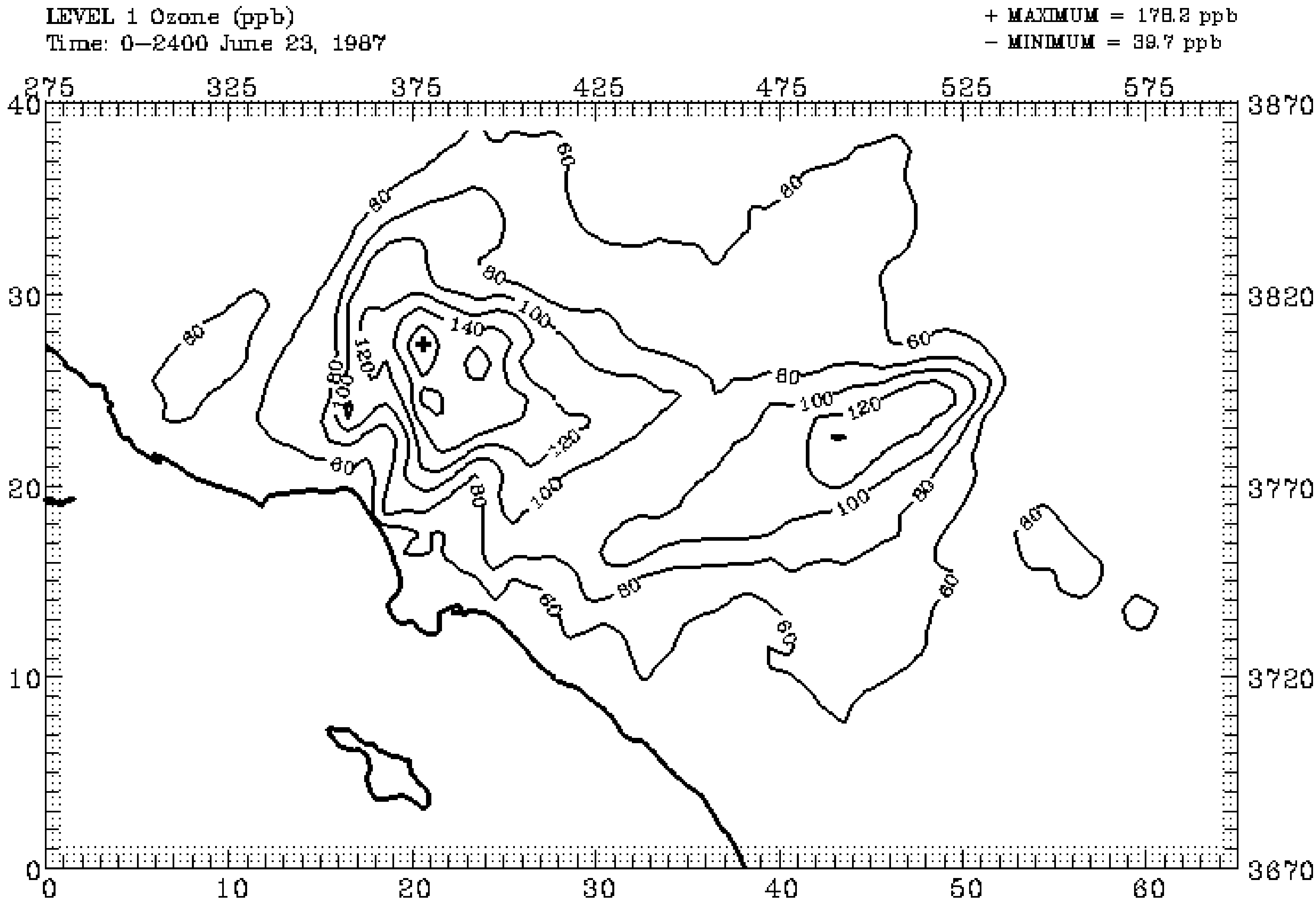


Figure 15a. Maximum simulated ozone concentrations for 50% NOx reduction with highflux CB4 - June 23, 1987.

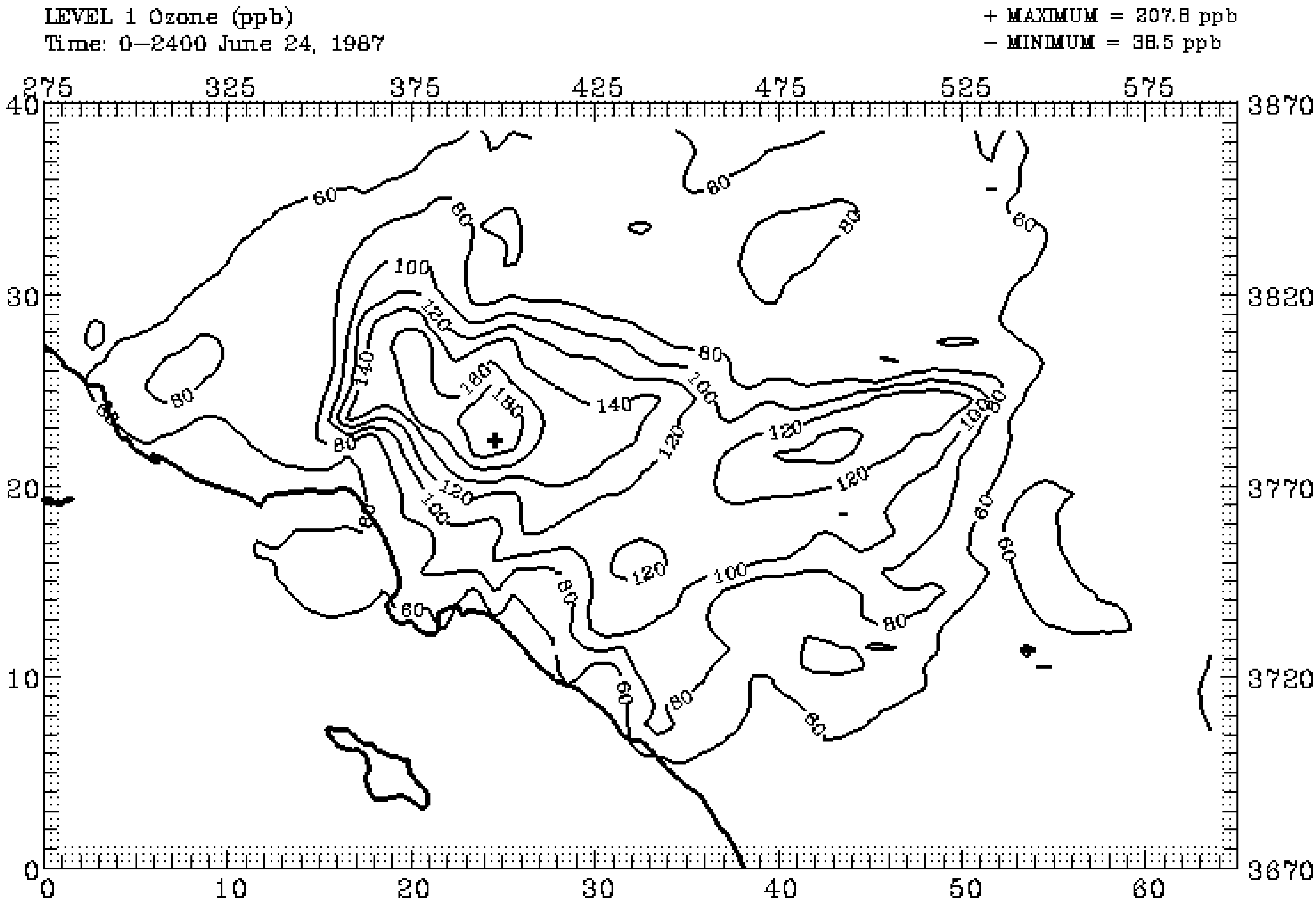


Figure 15b. Maximum simulated ozone concentrations for 50% NOx reduction with highflux CB4 - June 24, 1987.

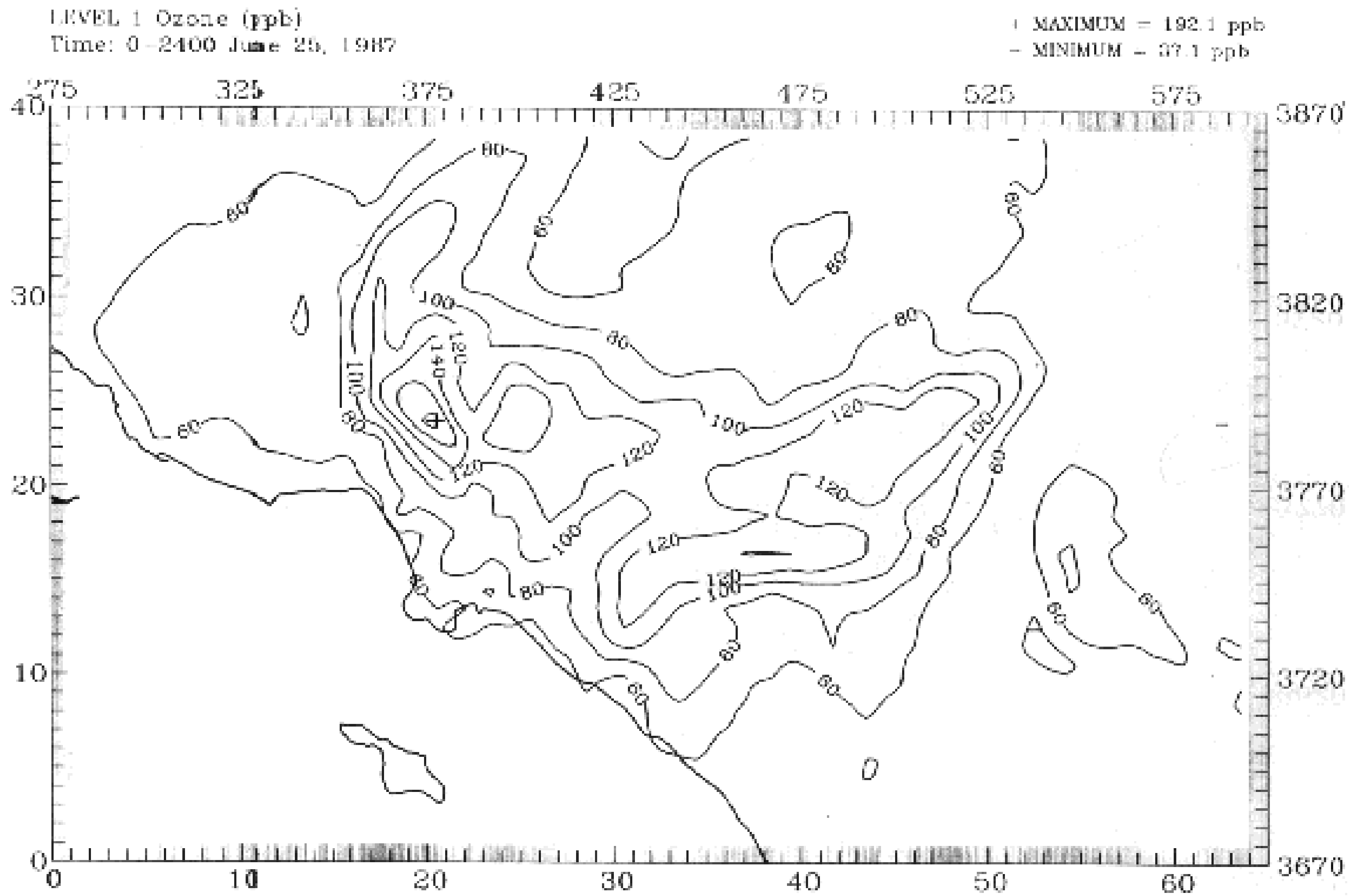


Figure 15c. Maximum simulated ozone concentrations for 50% NO_X reduction with highflux CB4 - June 25, 1987.

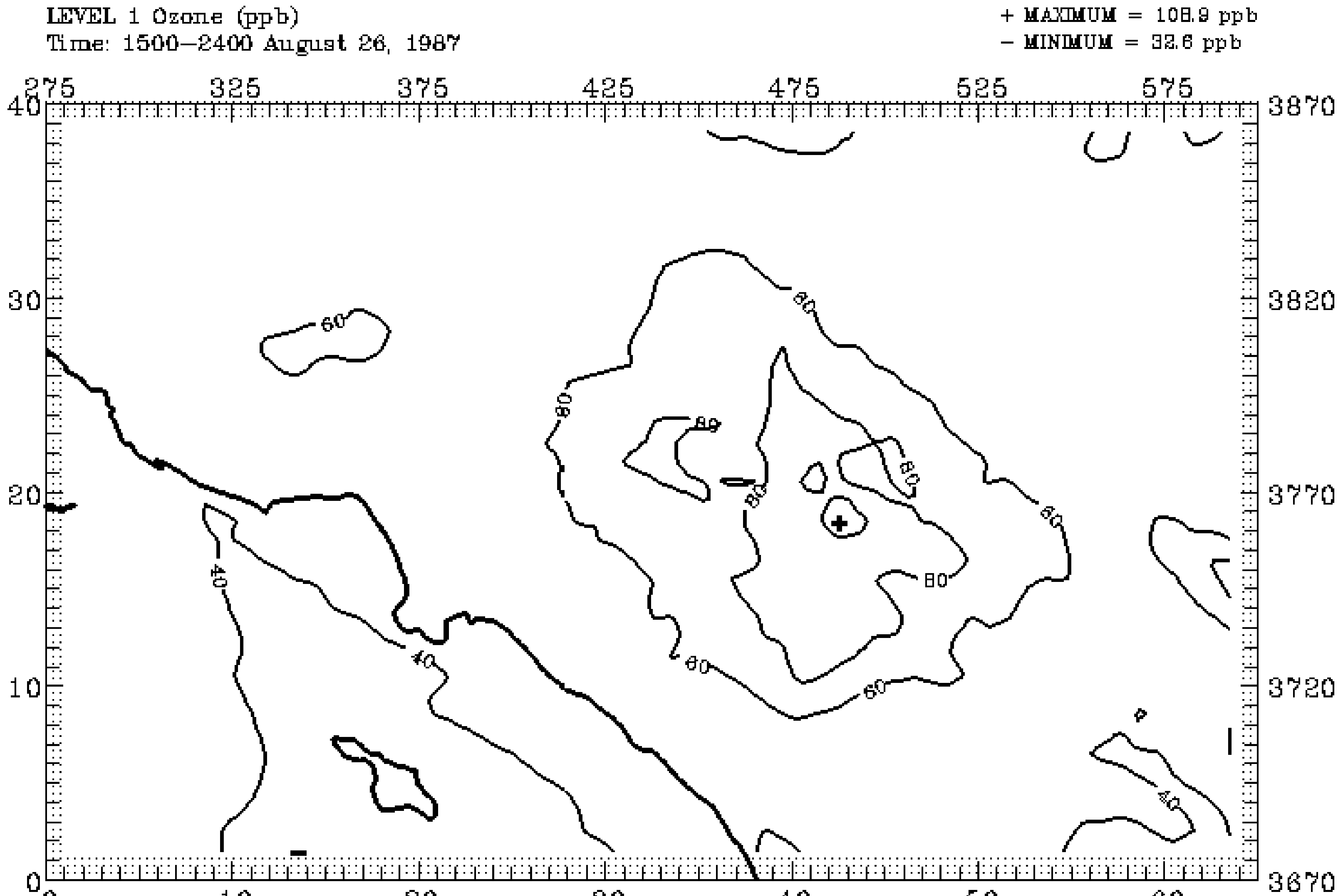


Figure 16a. Maximum simulated ozone concentrations for 50% NOx reduction with highflux CB4 - August 26, 1987.

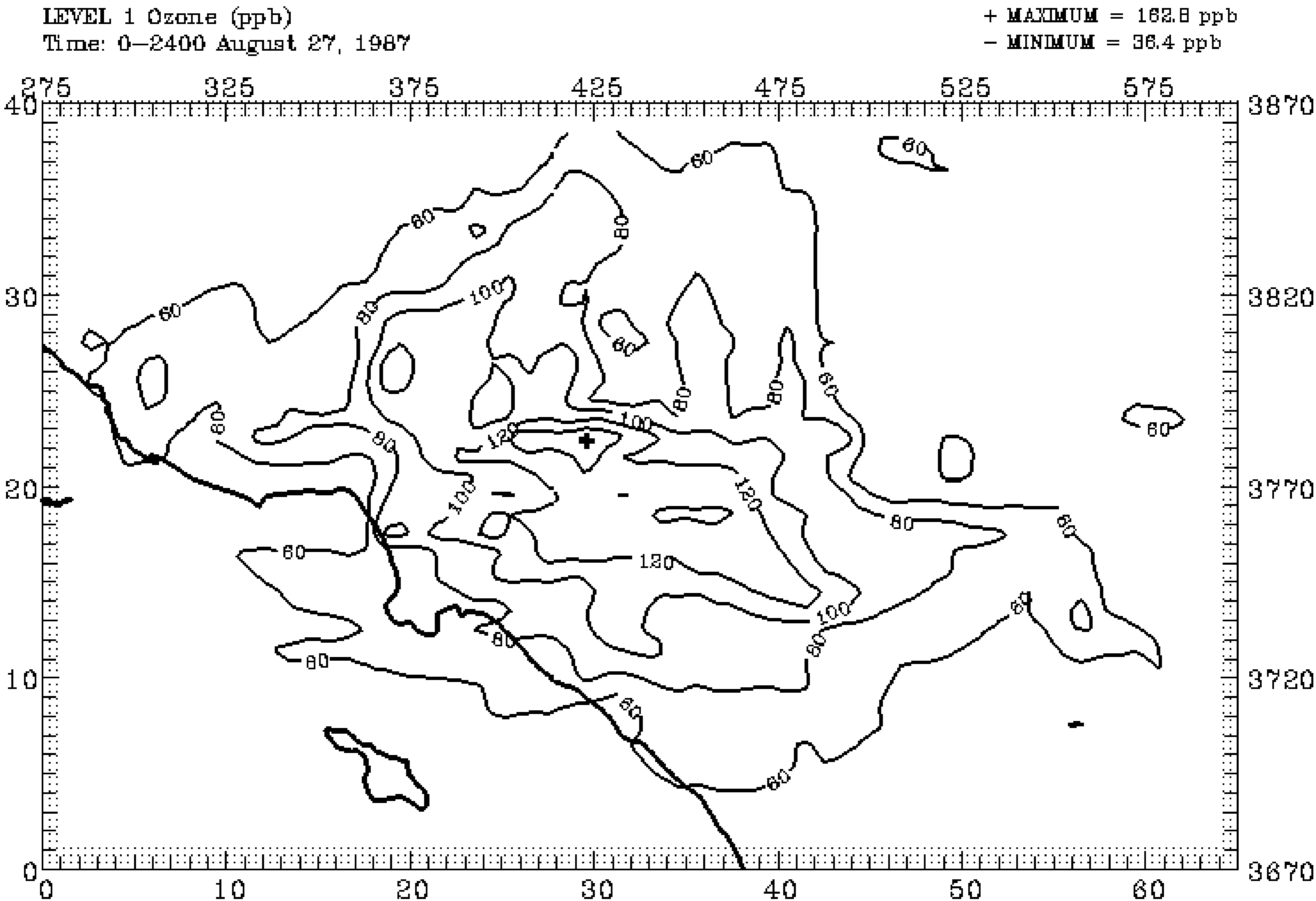


Figure 16b. Maximum simulated ozone concentrations for 50% NOx reduction with highflux CB4 - August 27, 1987.

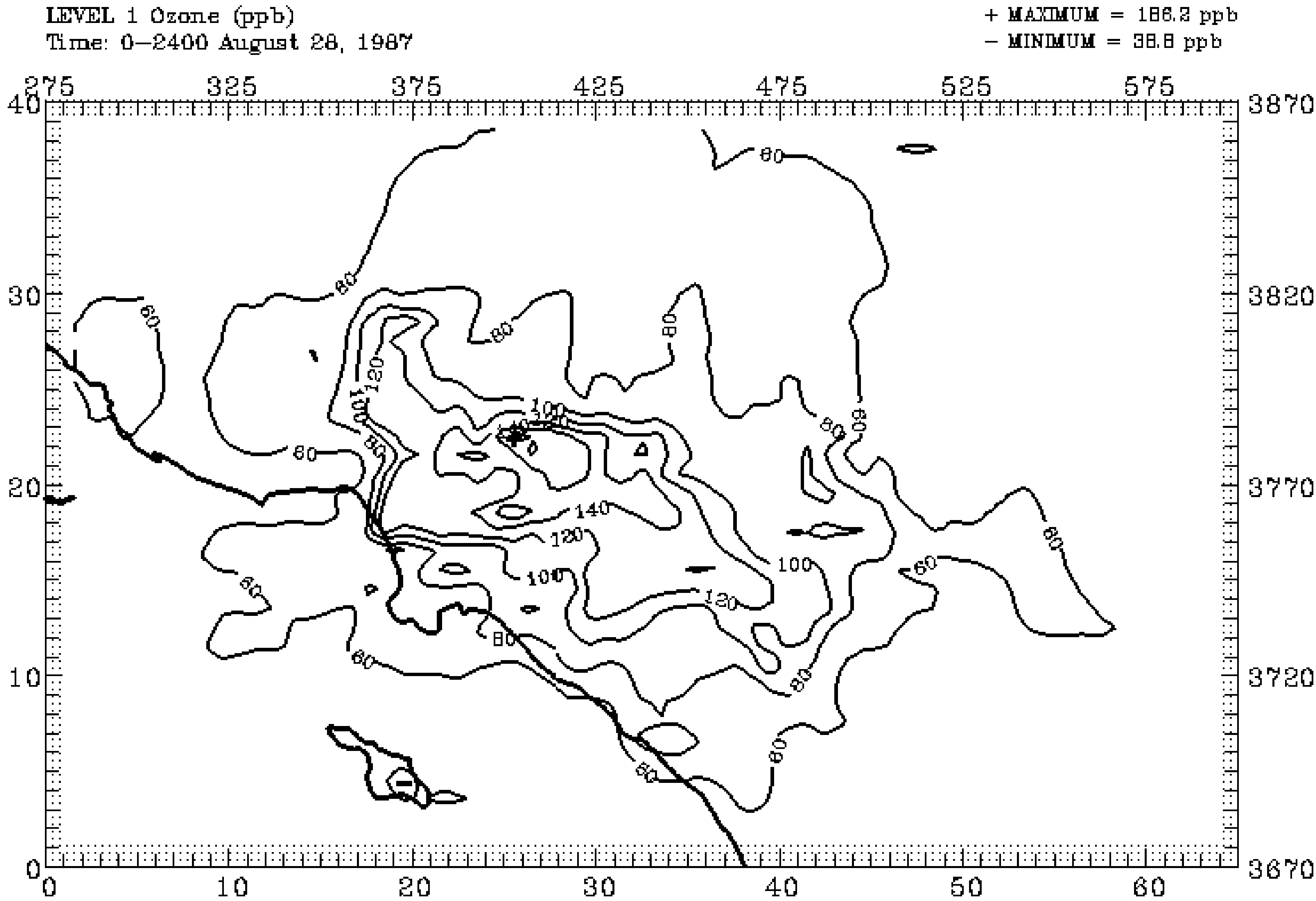


Figure 16c. Maximum simulated ozone concentrations for 50% NOx reduction with highflux CB4 - August 28, 1987.

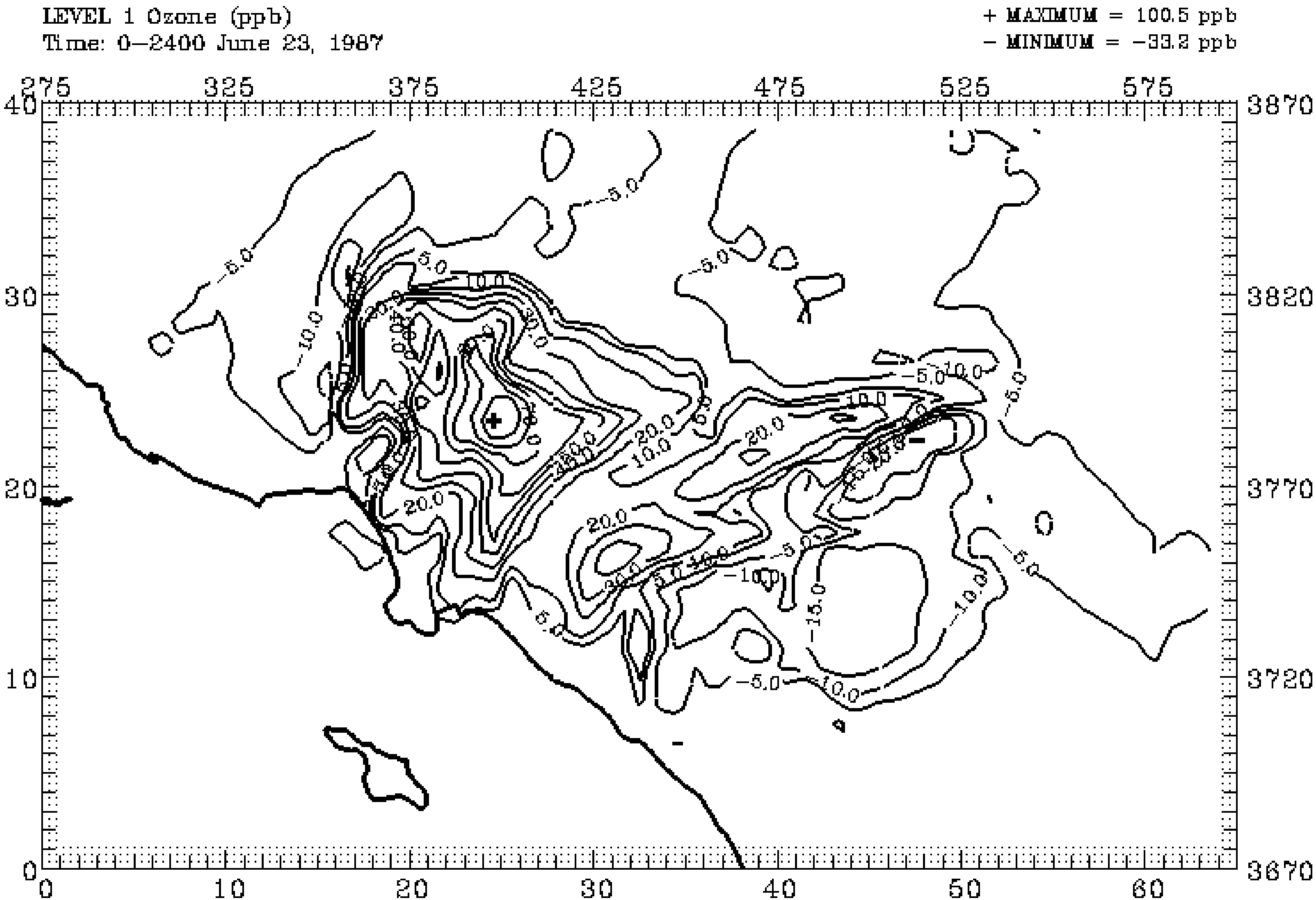


Figure 17a. Difference in maximum simulated ozone concentrations between NOx control run and base year run with highflux CB4 - June 23, 1987.

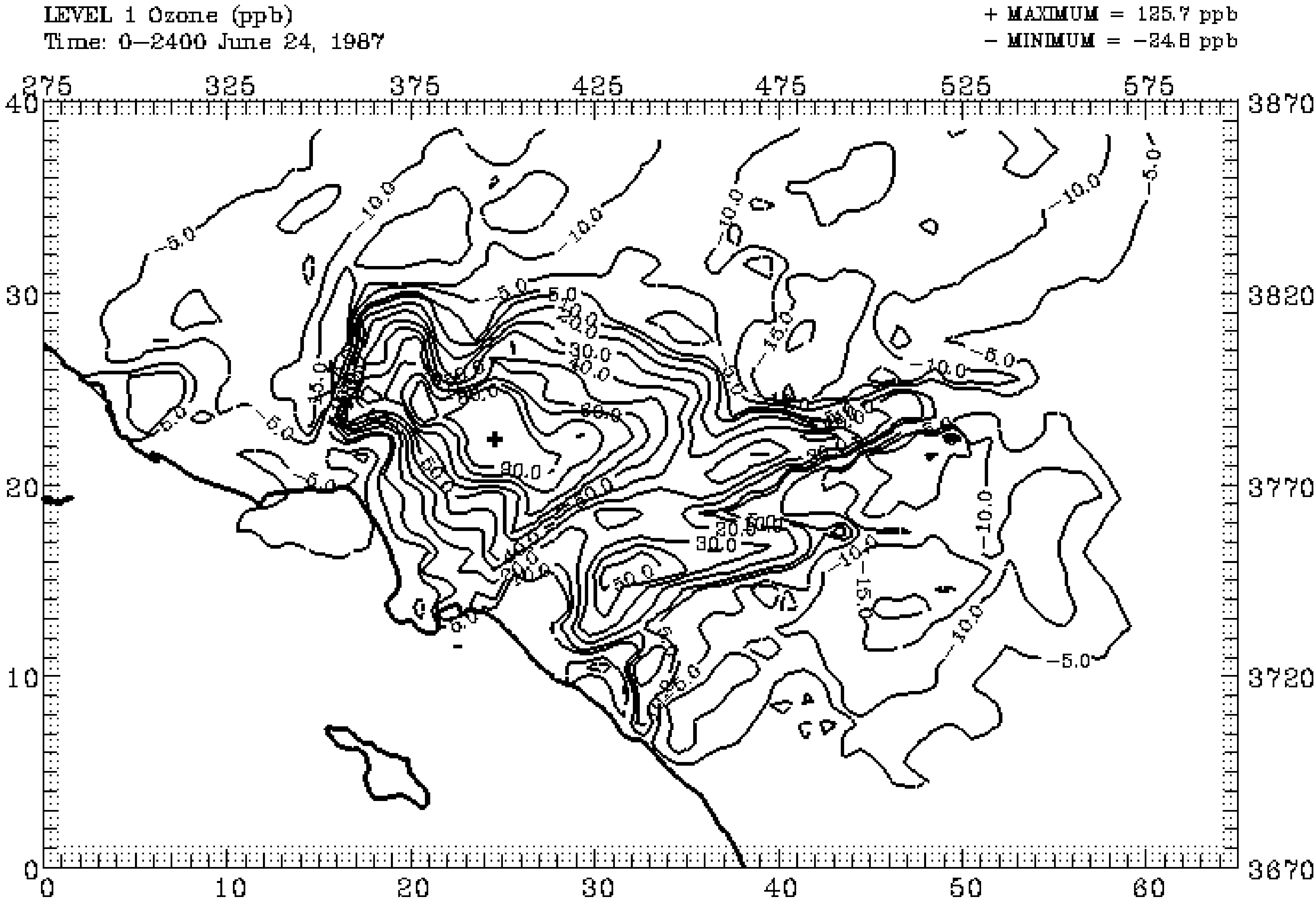


Figure 17b. Difference in maximum simulated ozone concentrations between NOx control run and base year with highflux CB4 - June 24, 1987.

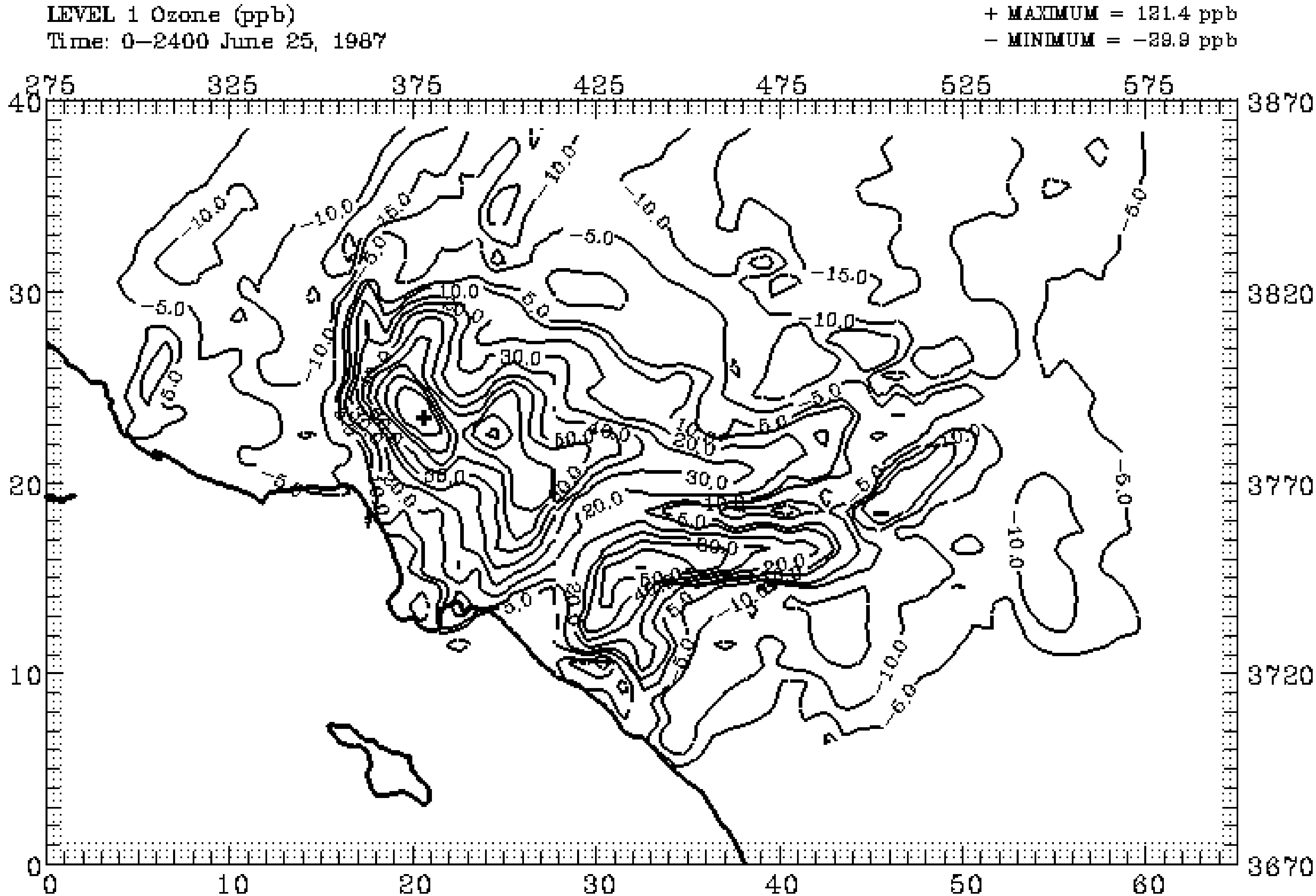


Figure 17c. Difference in maximum simulated ozone concentrations between NOx control run and base year run with highflux CB4 - June 25, 1987.

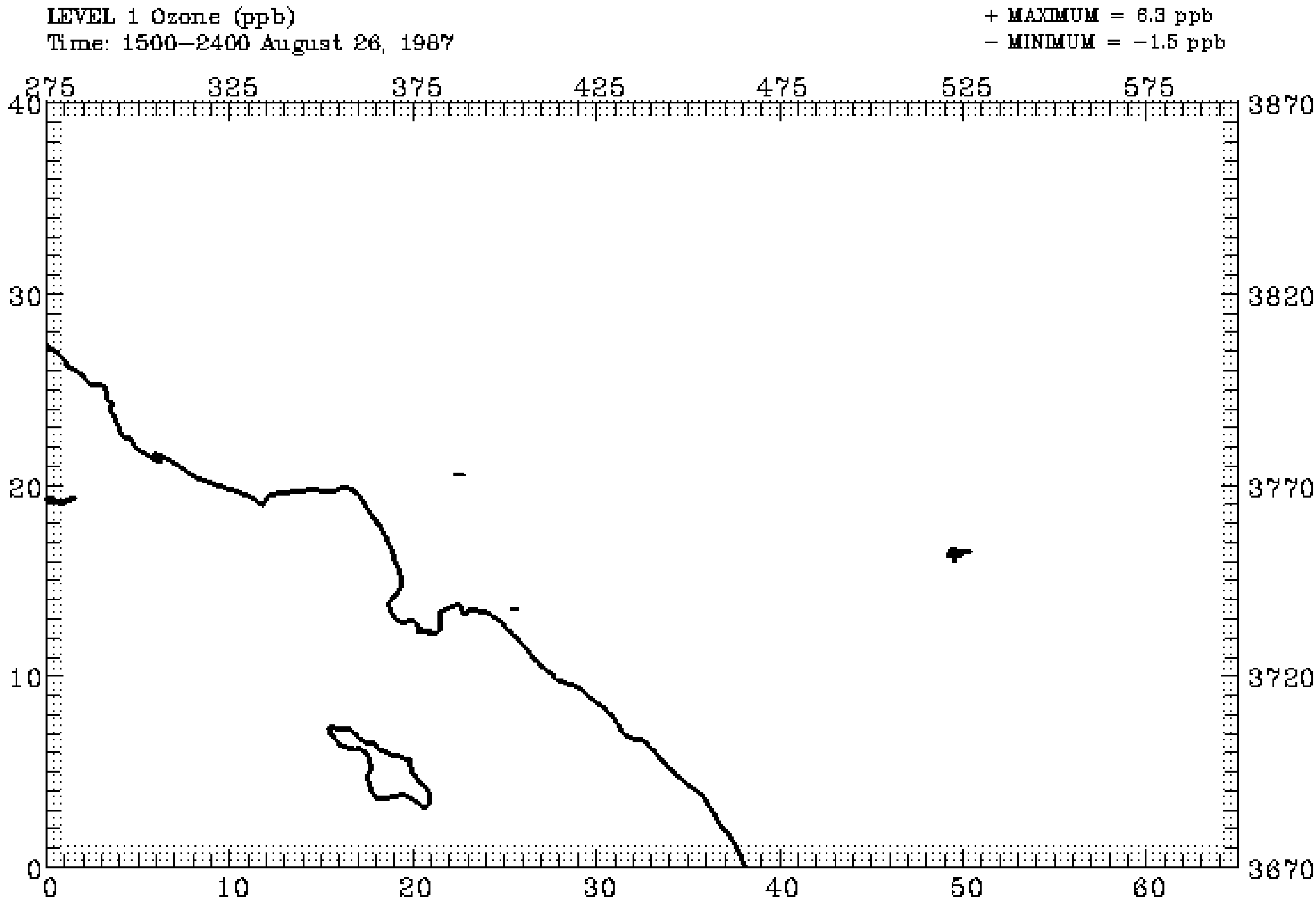


Figure 18a. Difference in maximum simulated ozone concentrations between NOx control run and base year run with highflux CB4 - August 26, 1987

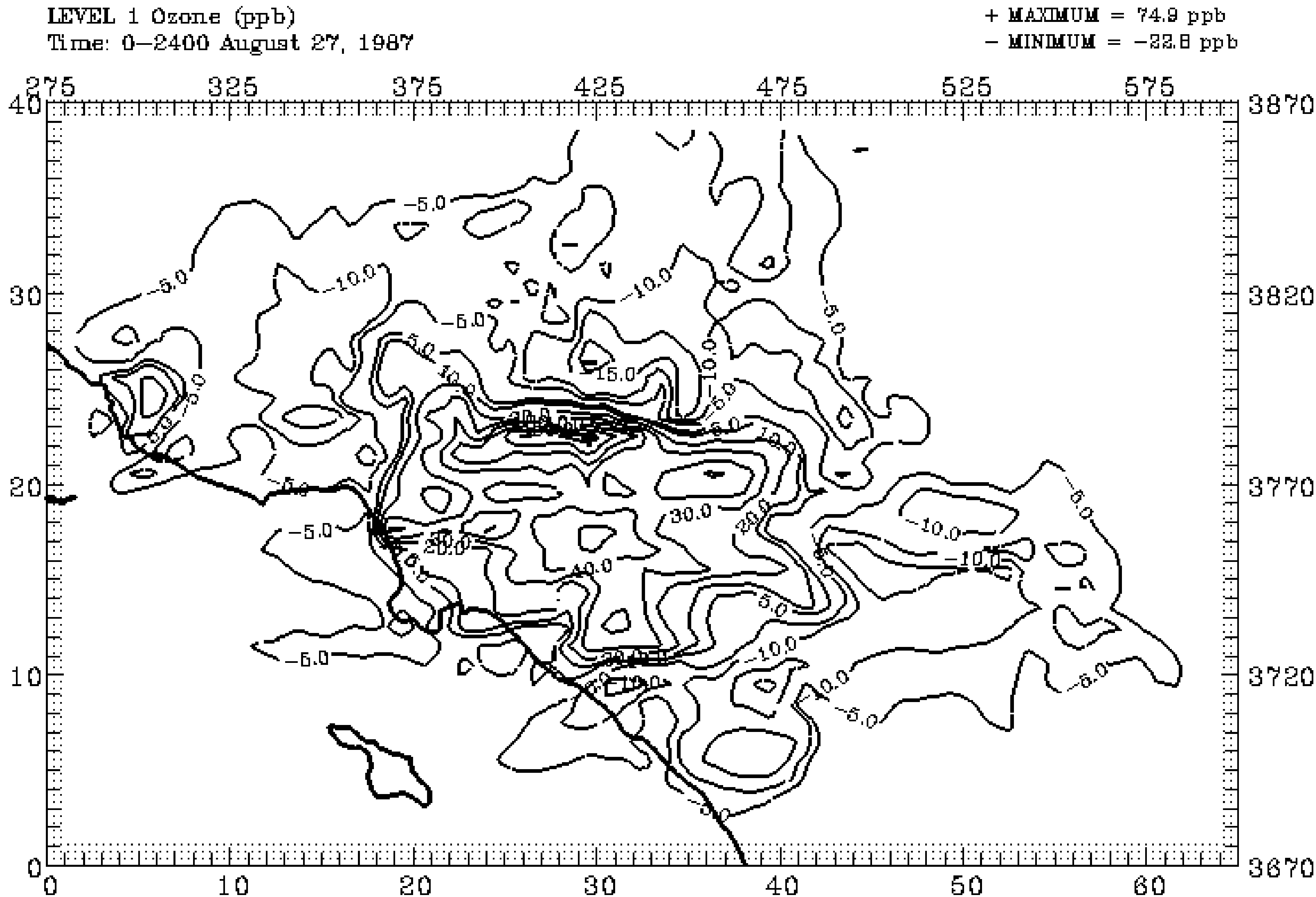


Figure 18b. Difference in maximum simulated ozone concentrations between NOx control run and base year run with highflux CB4 - August 27, 1987.

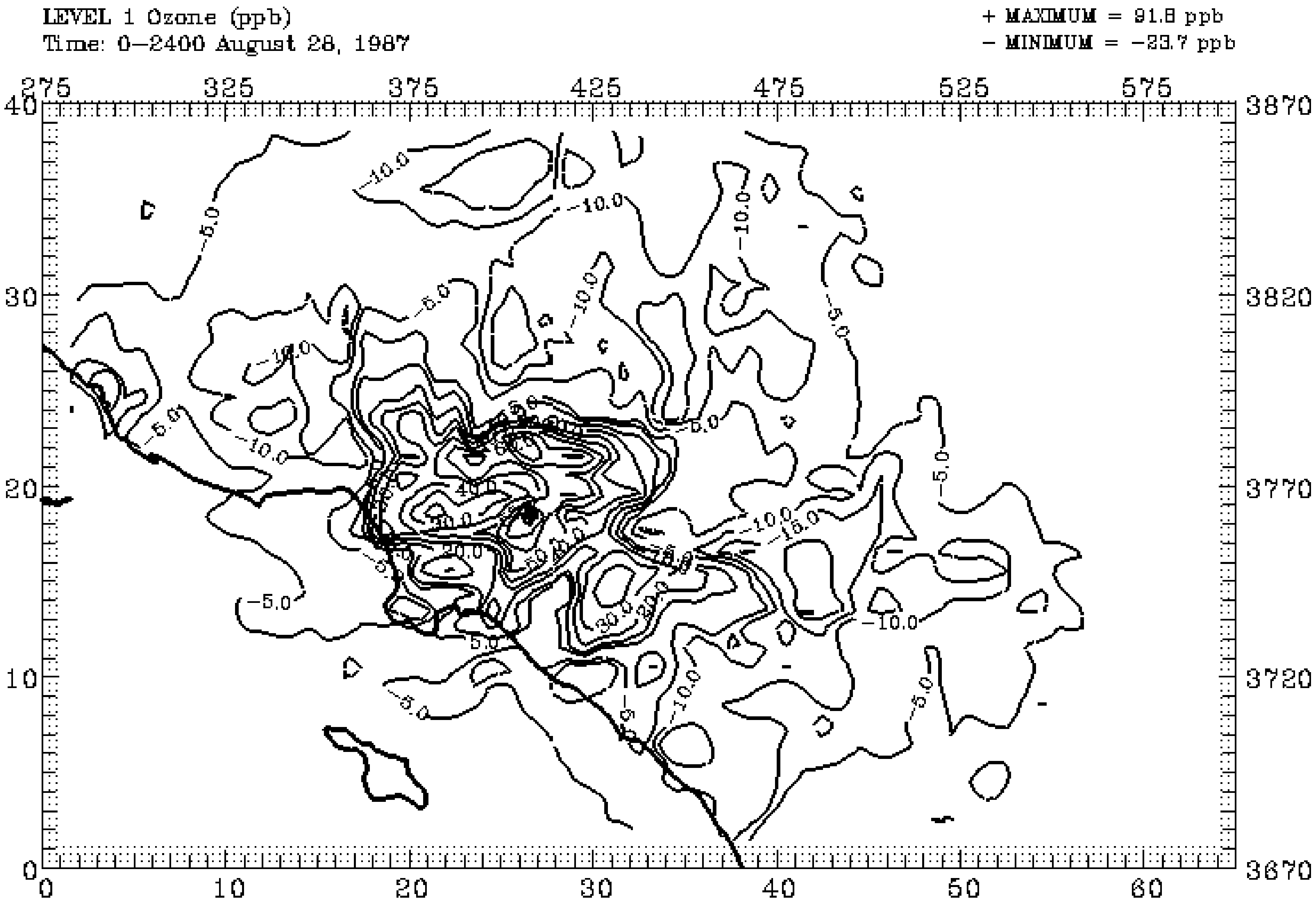


Figure 18c. Difference in maximum simulated ozone concentrations between NOx control run and base year run with highflux CB4 - August 28, 1987.

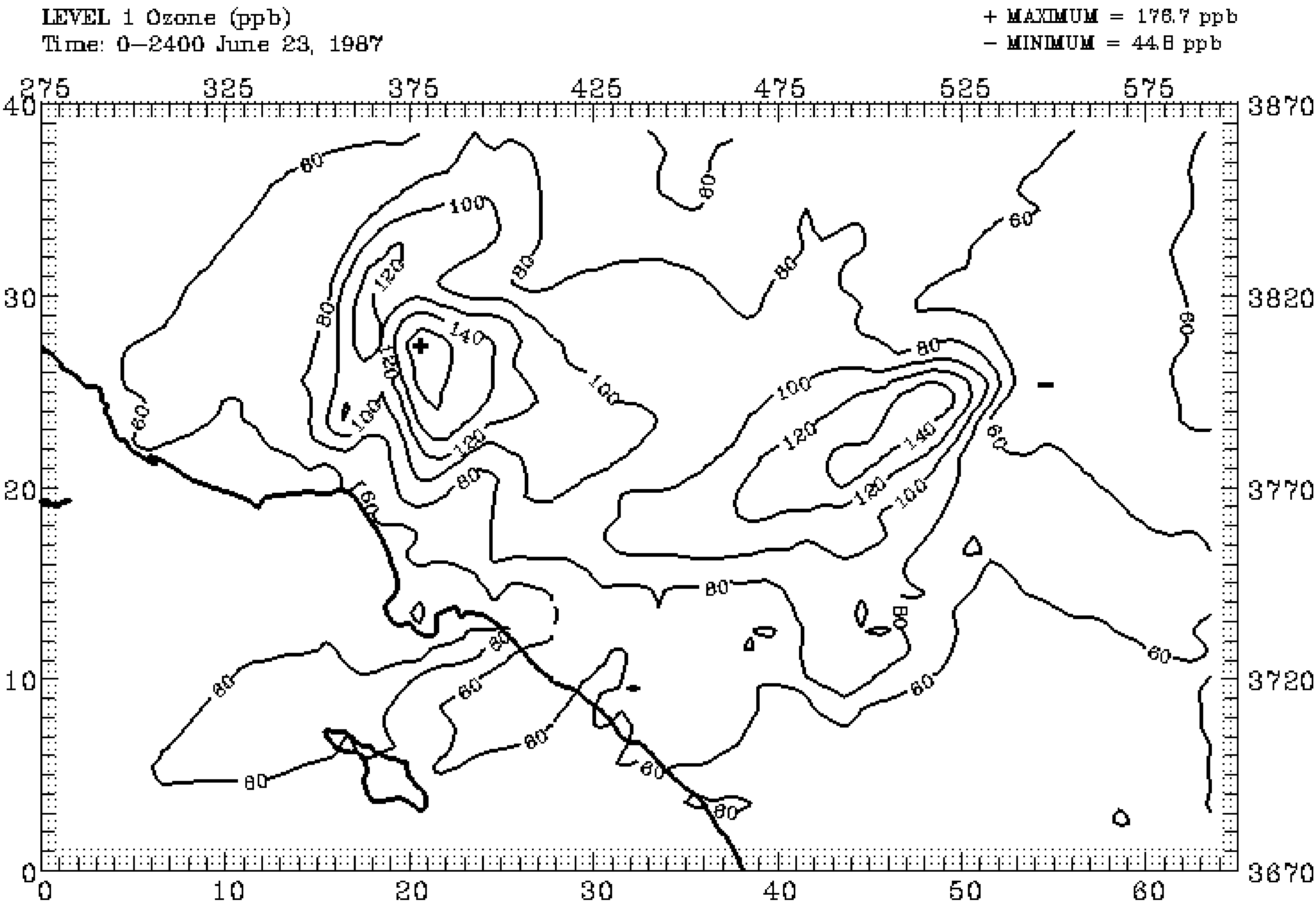


Figure 19a. Maximum simulated ozone concentrations fo 50% NOx reduction with lowflux CB4 - June 23, 1987.

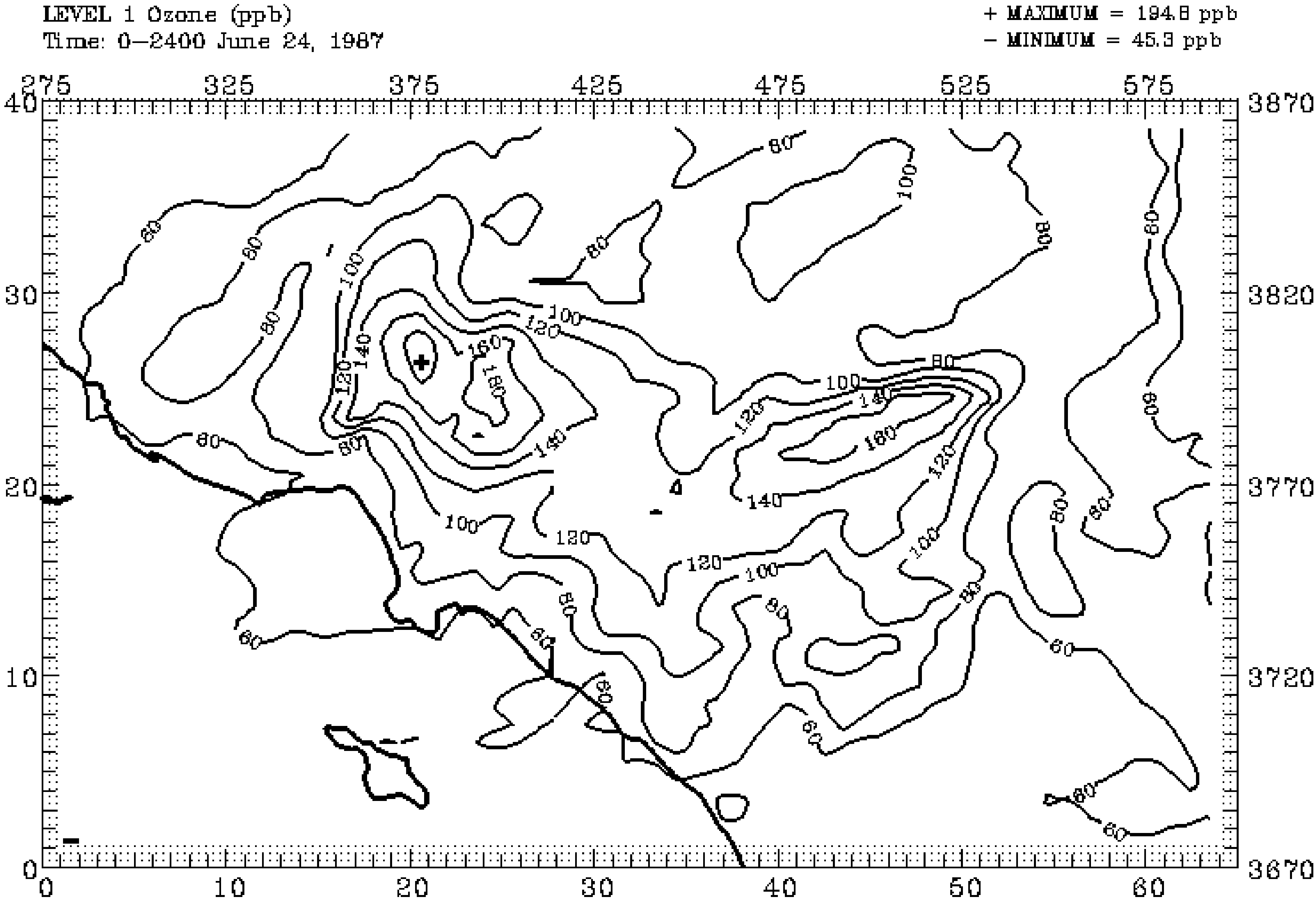


Figure 19b. Maximum simulated ozone concentrations for 50% NOx reduction with lowflux CB4 - June 24, 1987.

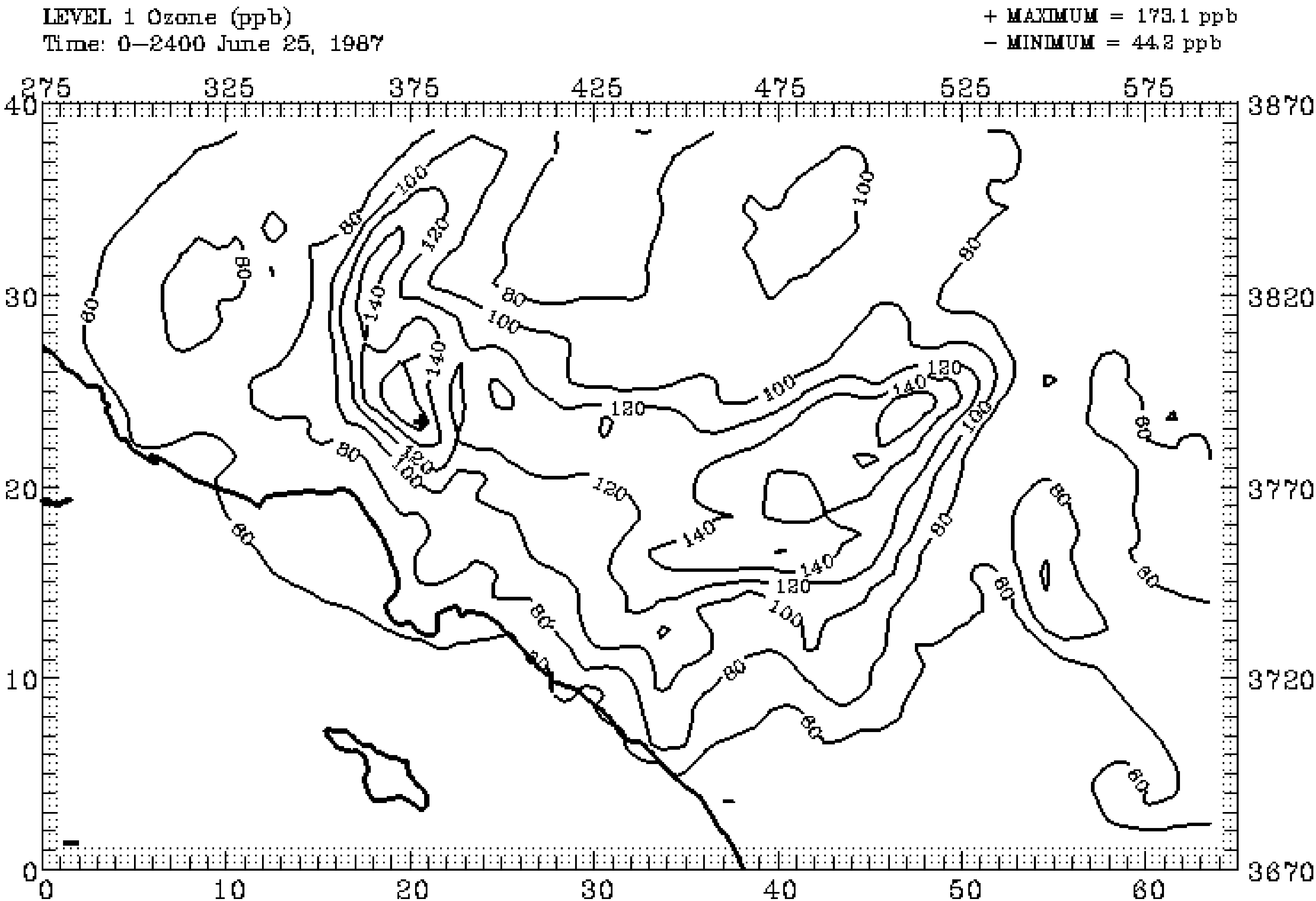


Figure 19c. Maximum simulated ozone concentrations for 50% NOx reduction with lowflux CB4 - June 25, 1987.

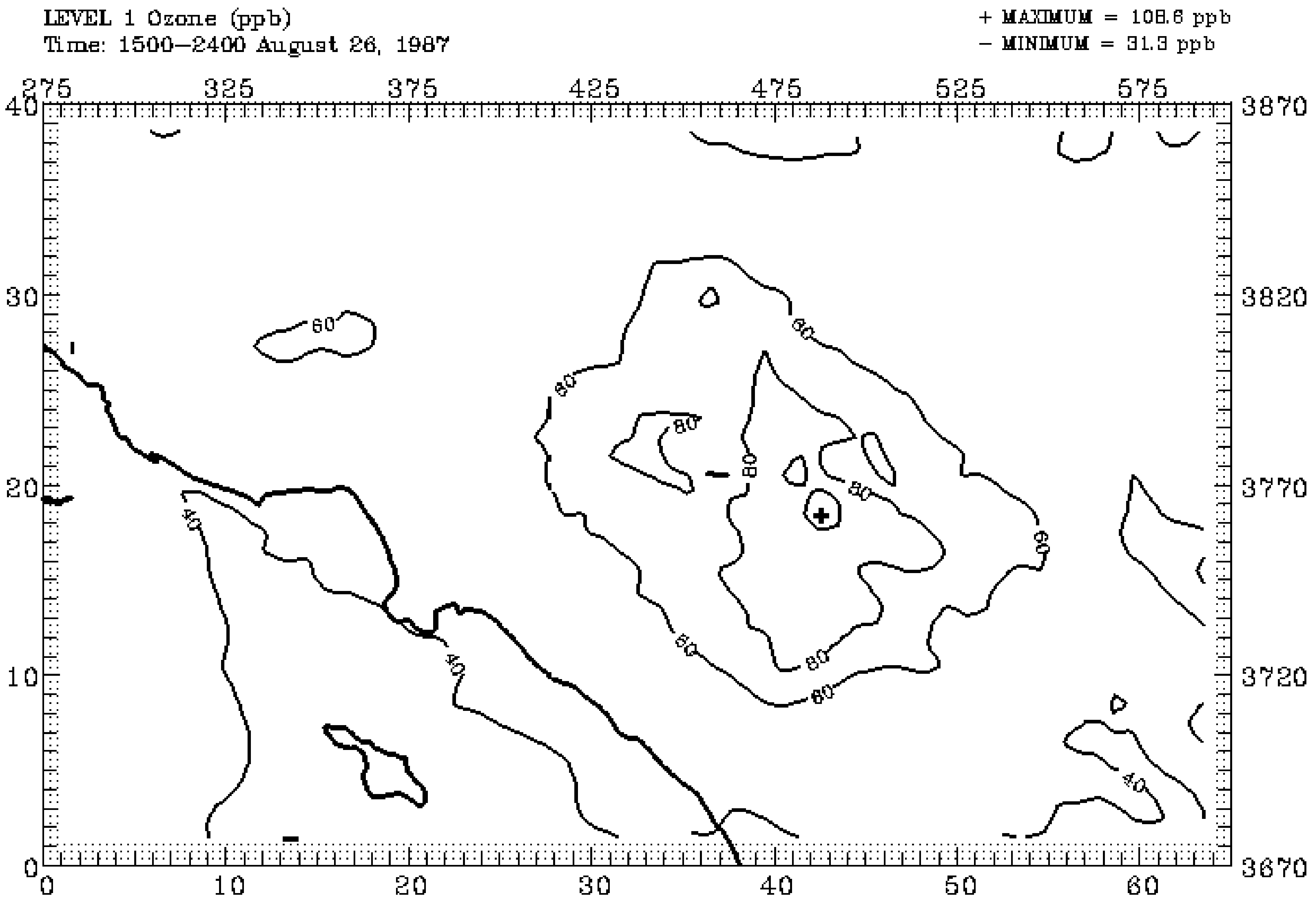


Figure 20a. Maximum simulated ozone concentrations for 50% NOx reduction with lowflux CB4 - August 26,1987.

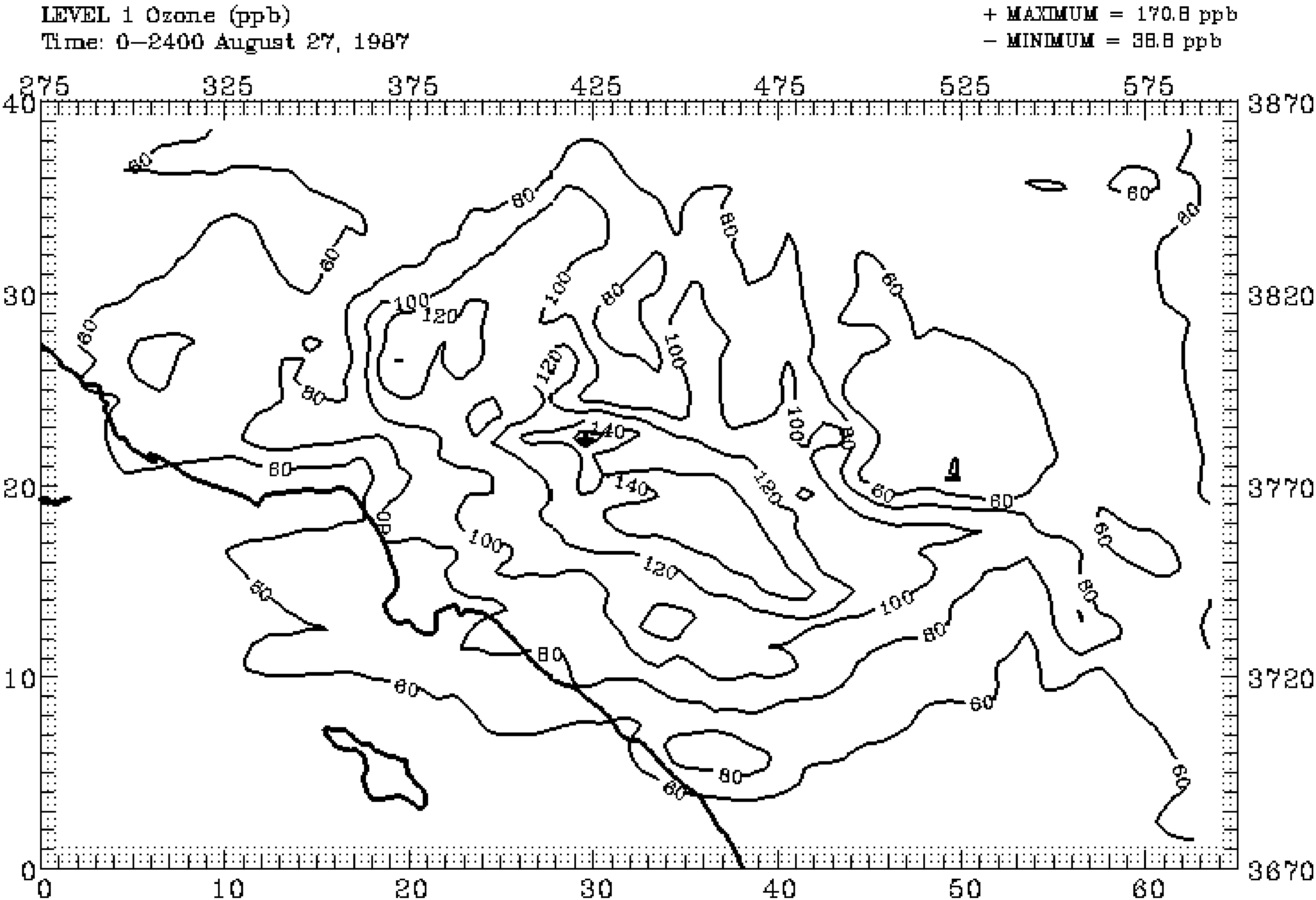


Figure 20b. Maximum simulated ozone concentrations for 50% NOx reduction with lowflux CB4 - August 27, 1987.

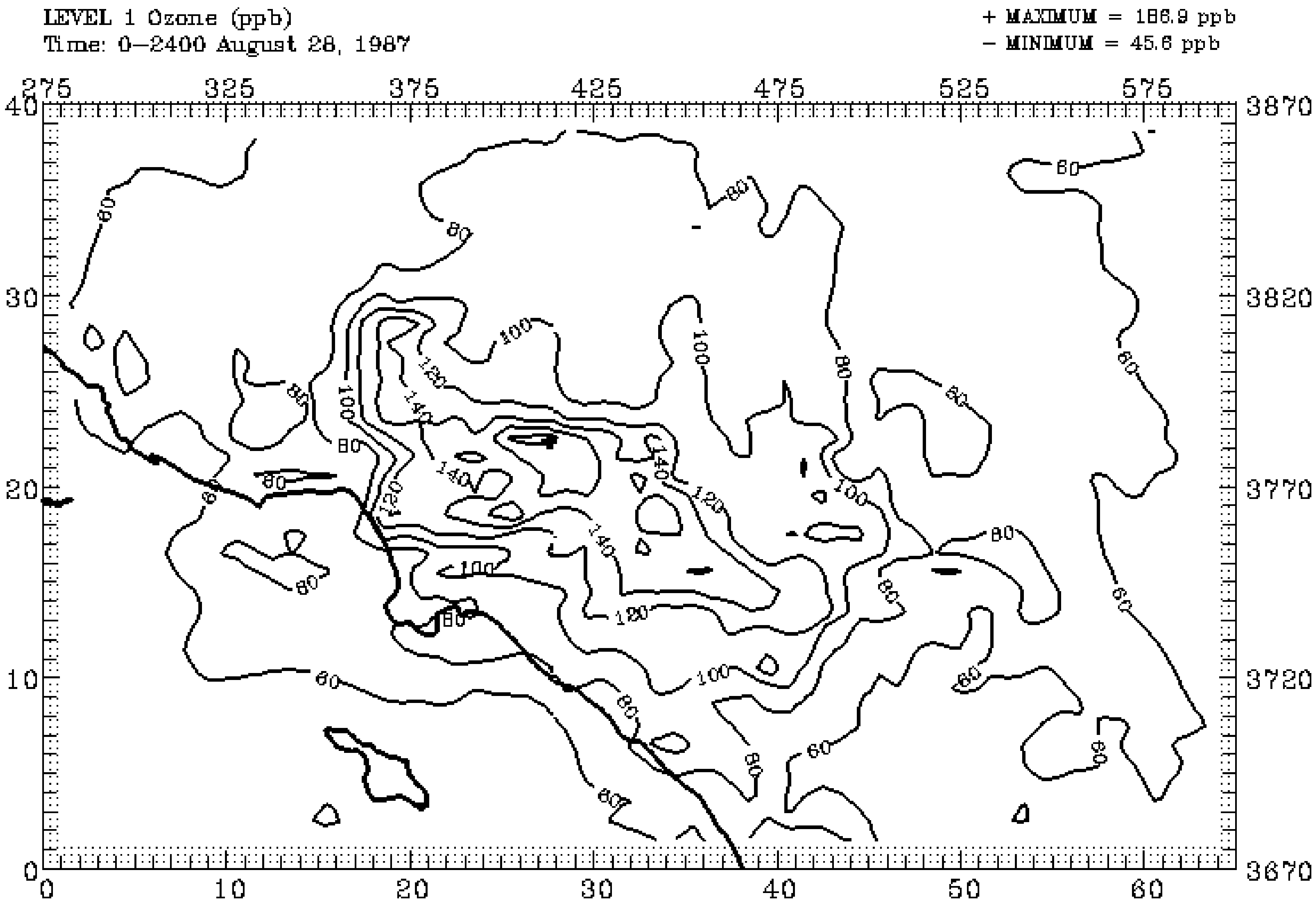


Figure 20c. Macimum simulated ozone concentrations for 50% NOx reduction with lowflux CB4 - August 28 1987.

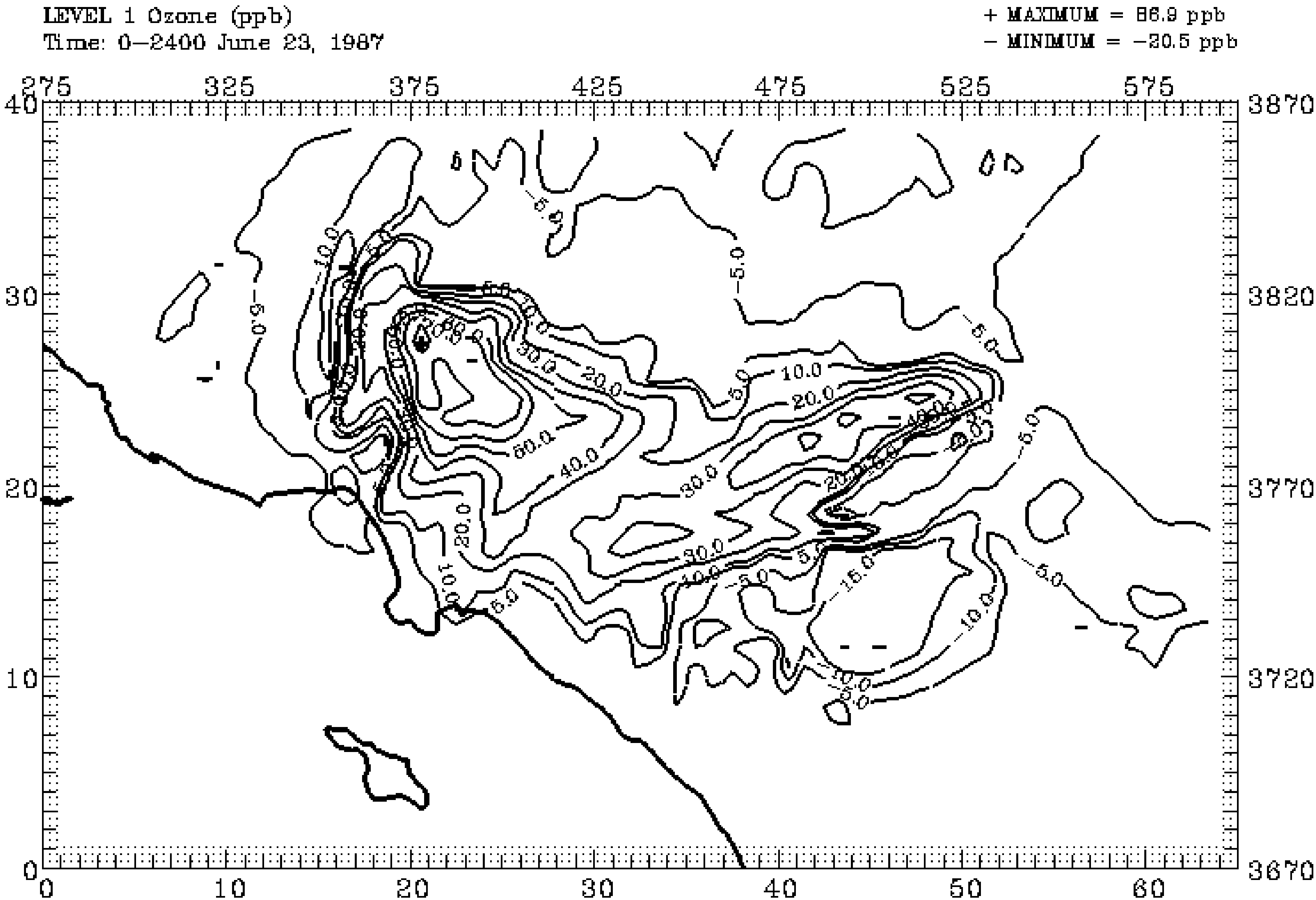


Figure 21a. Difference in maximum simulated ozone concentrations between NOx control run and base year run with lowflux CB4 - June 23, 1987.

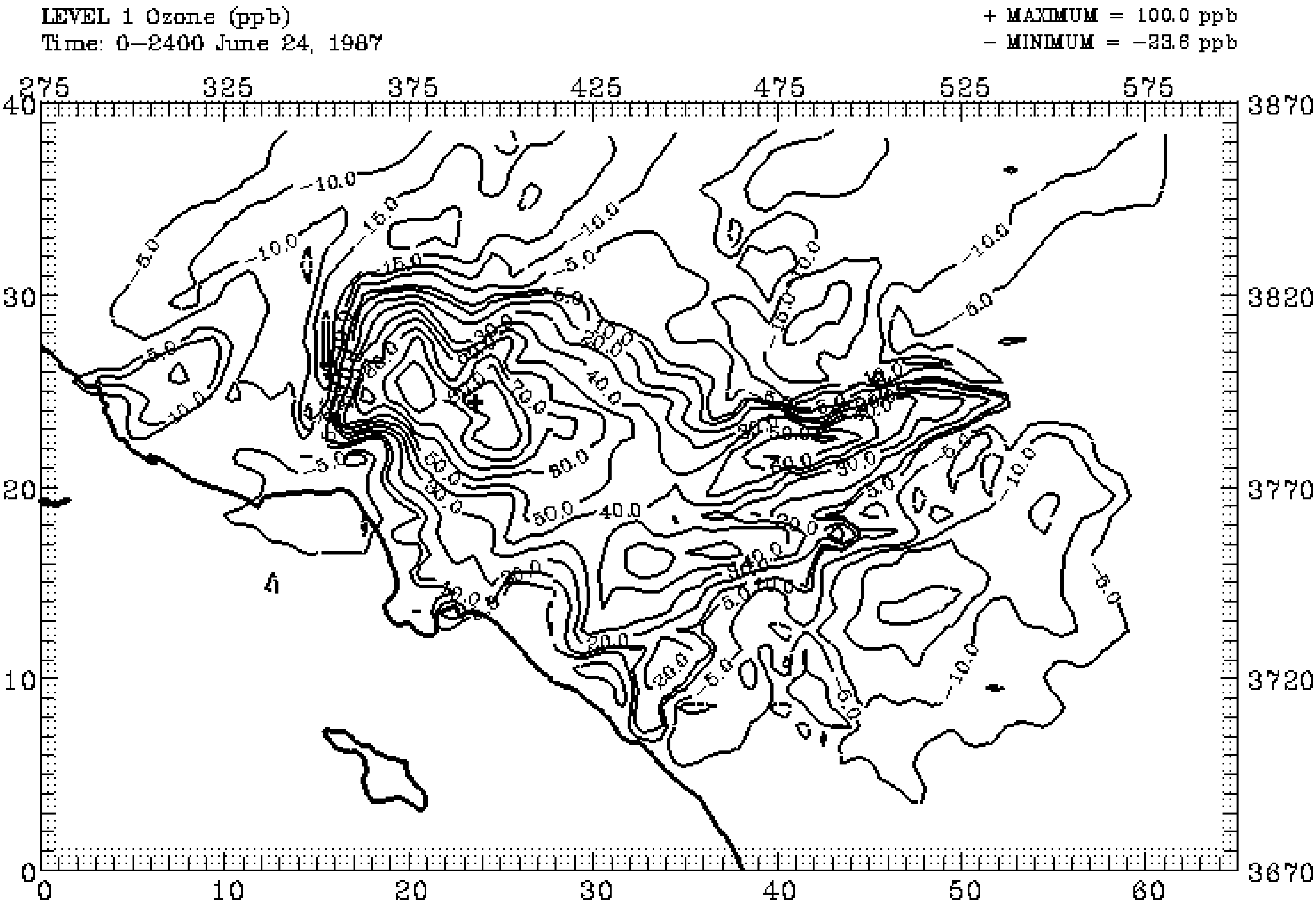


Figure 21b. Difference in maximum simulated ozone concentrations between NOx control run and base year run with lowflux CB4 - June 24, 1987.

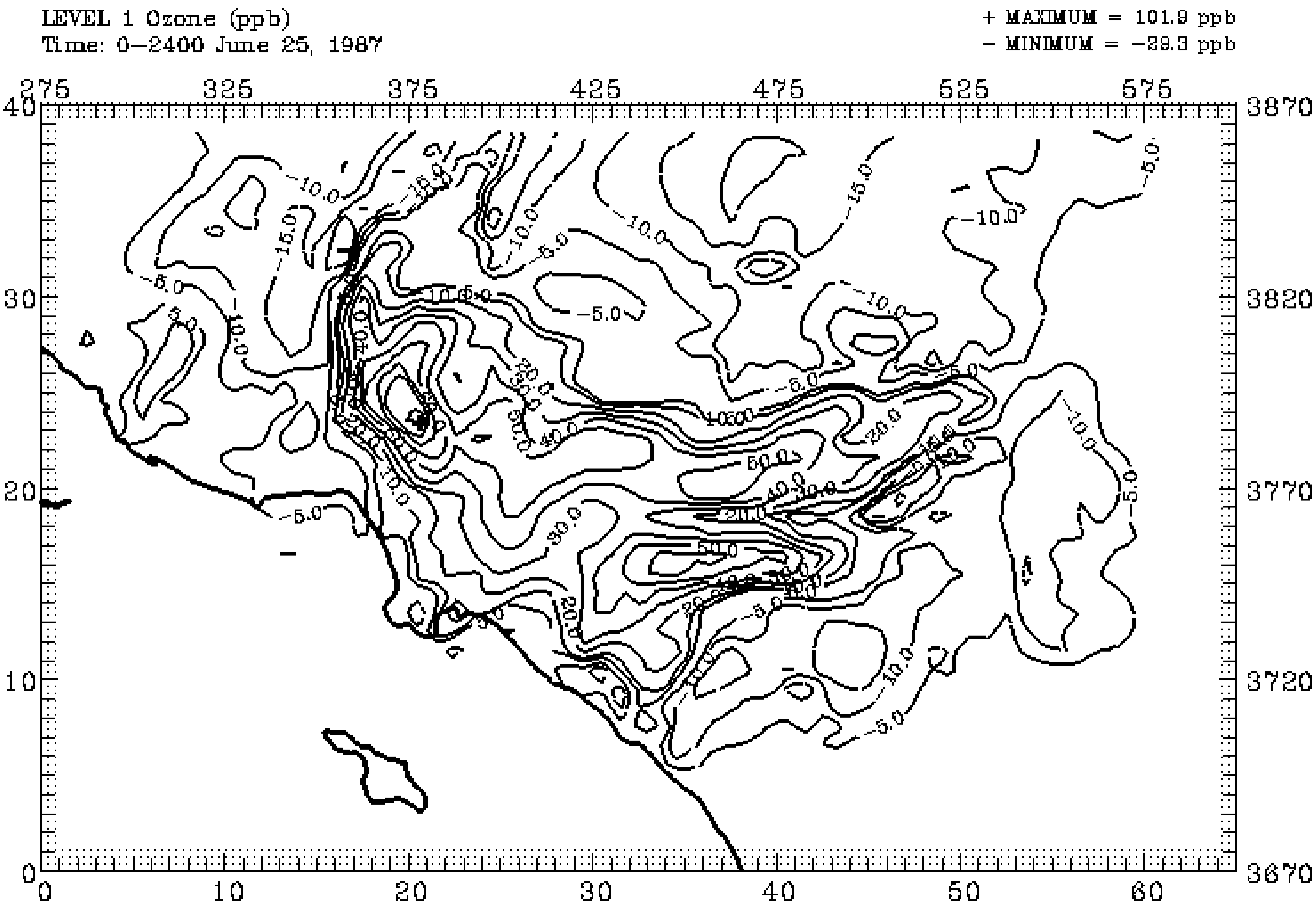


Figure 21c. Difference in maximum simulated ozone concentrations between NOx control run and base year run with lowflux CB4 - June 25, 1987.

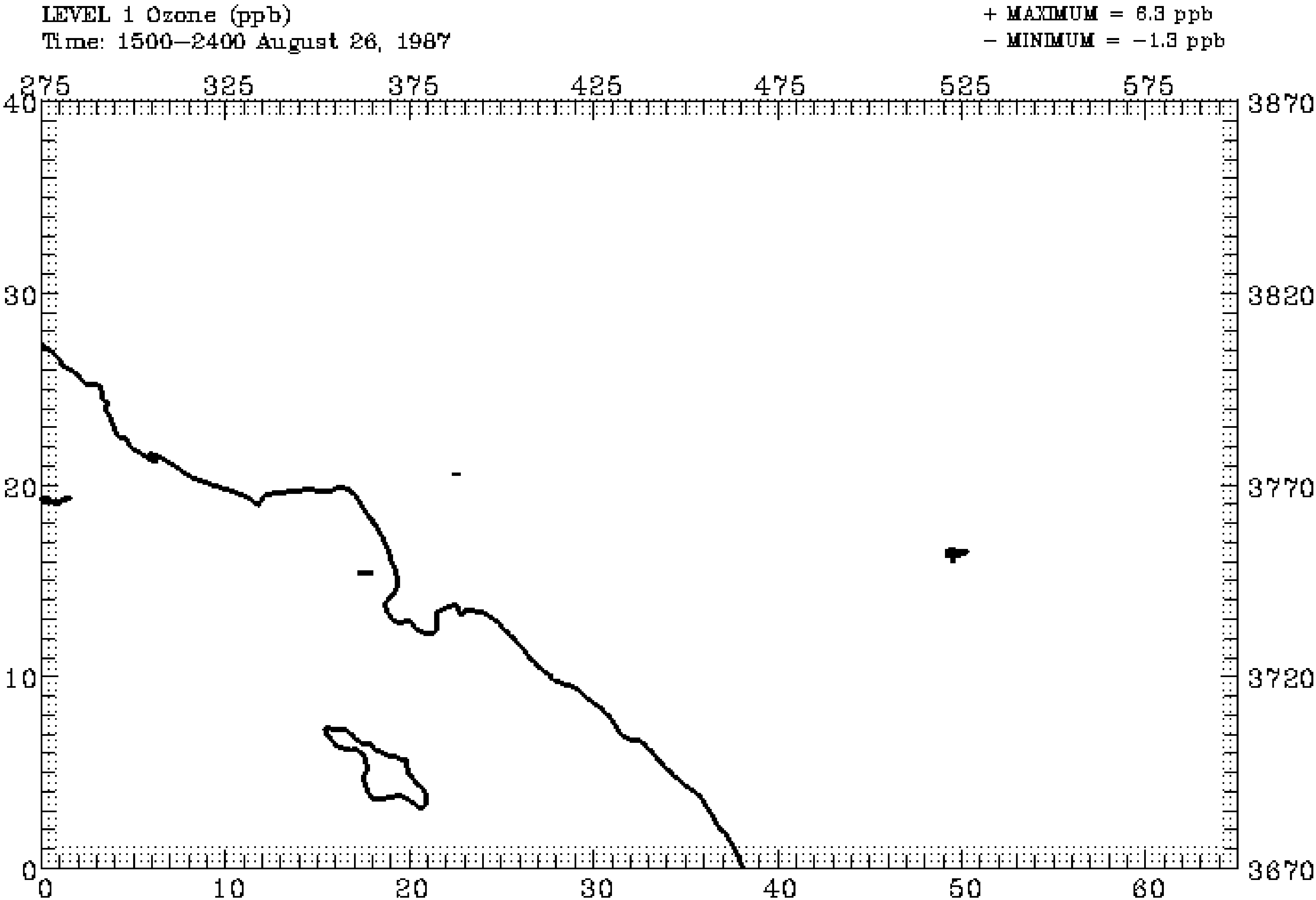


Figure 22a. Difference in maximum simulated ozone concentrations between NOx control run and base year run with lowflux CB4 - August 26, 1987.

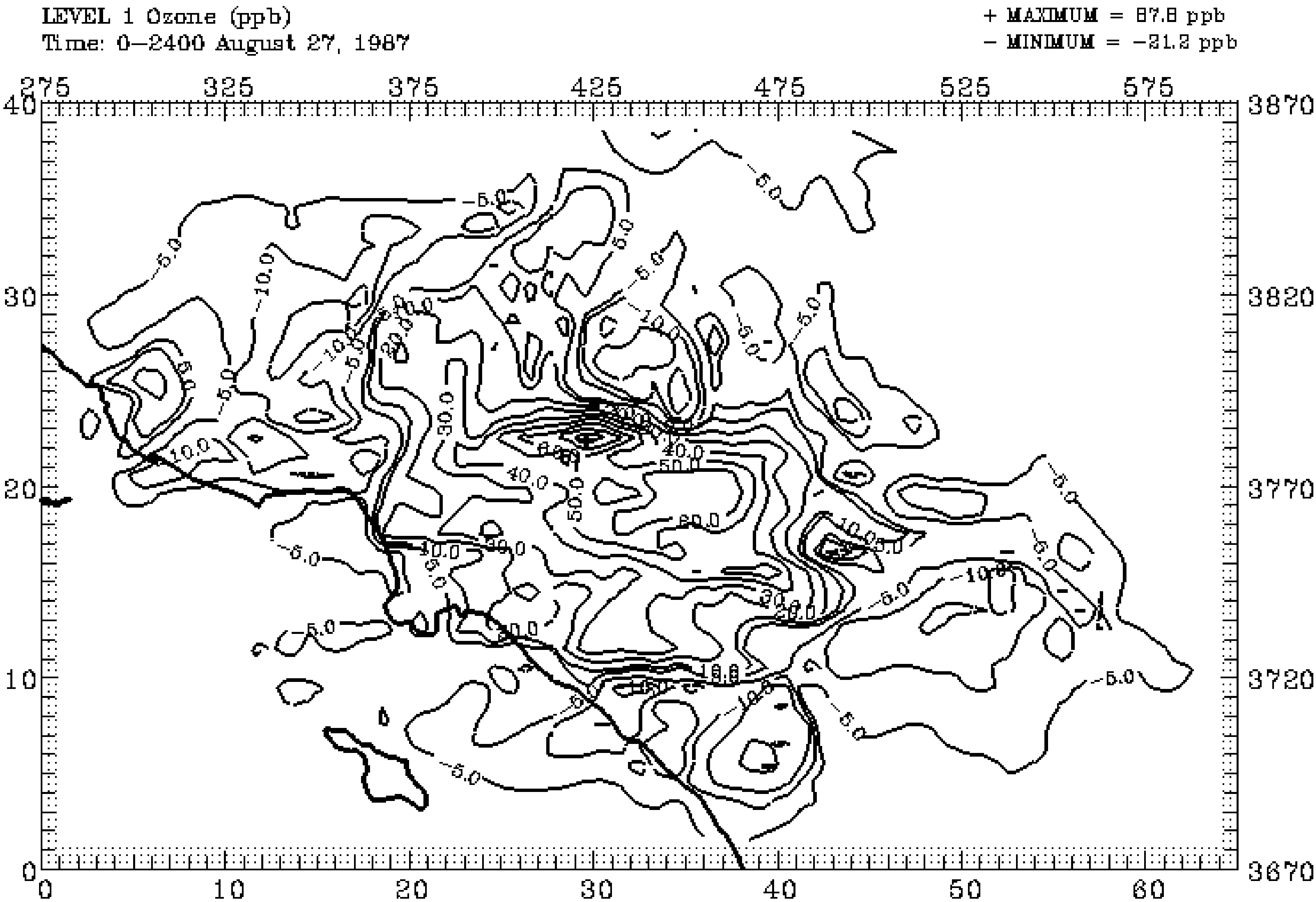


Figure 22b. Difference in maximum simulated ozone concentrations between NOx control run and base year run with lowflux CB4 - August 27, 1987.

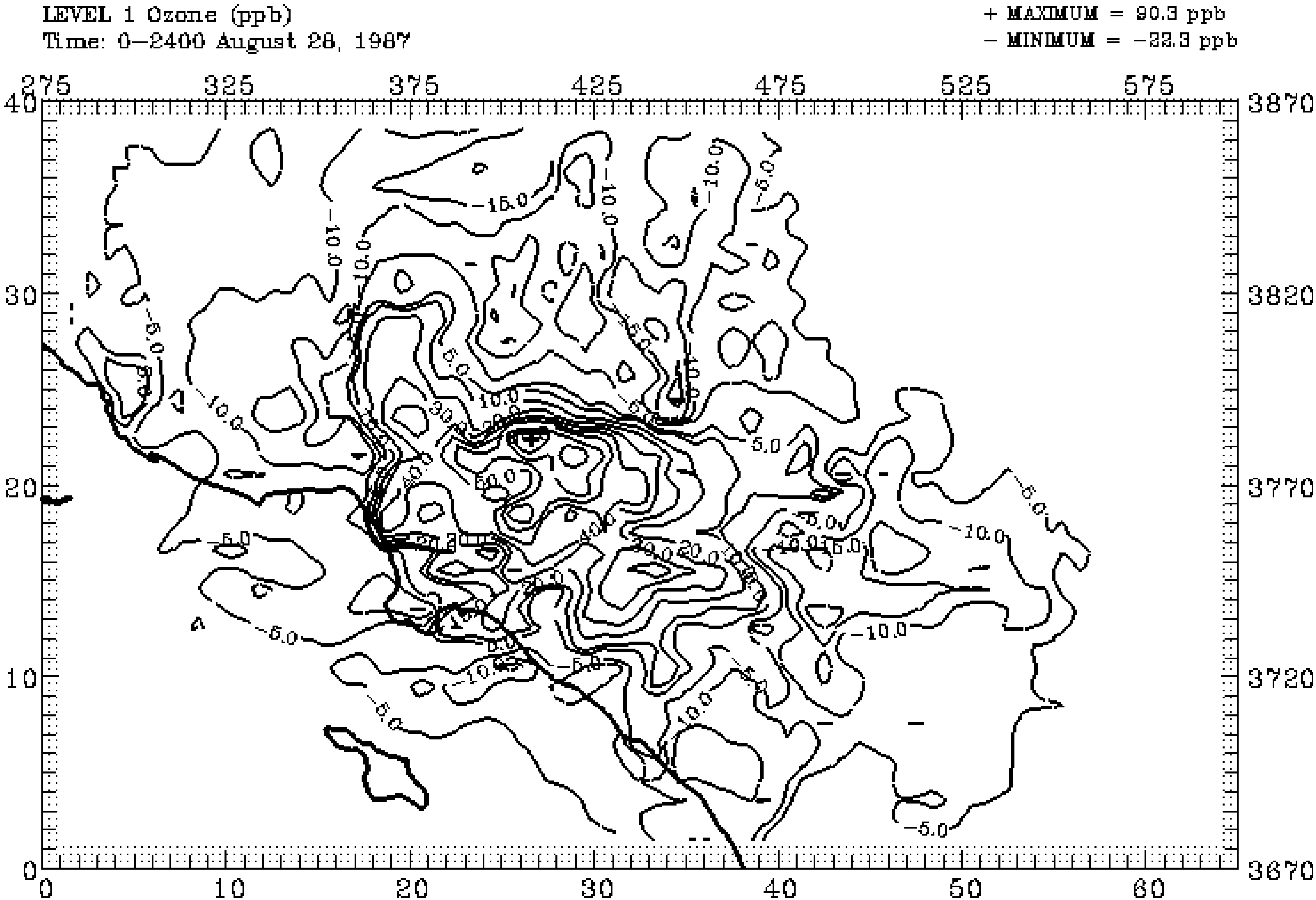


Figure 22c. Difference in maximum simulated ozone concentrations between NOx control run and base year run with lowflux CB4 - August 28, 1987.

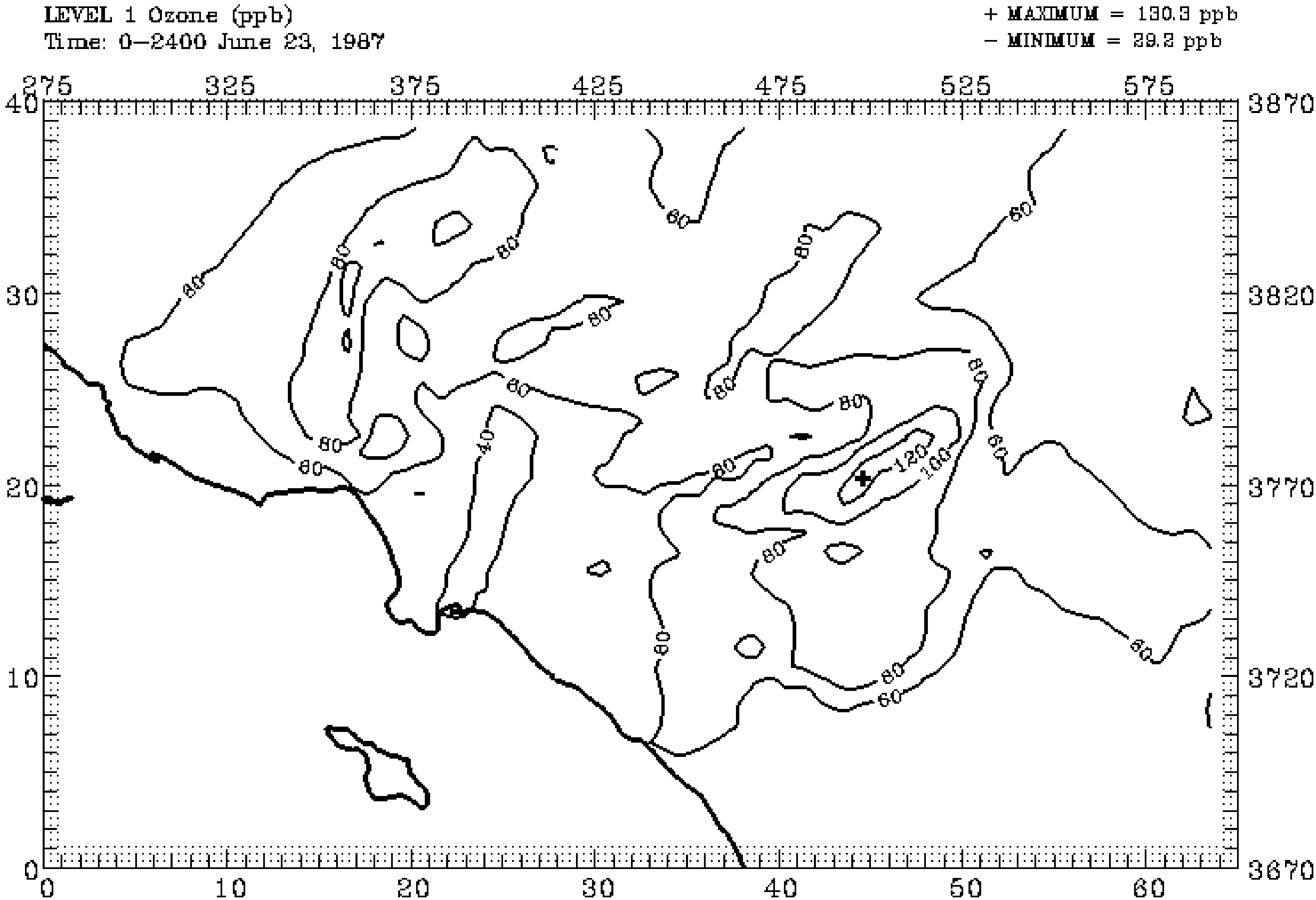


Figure 23a. Maximum simulated ozone concentrations for 50% VOC reduction with standard CB4 - June 23, 1987.

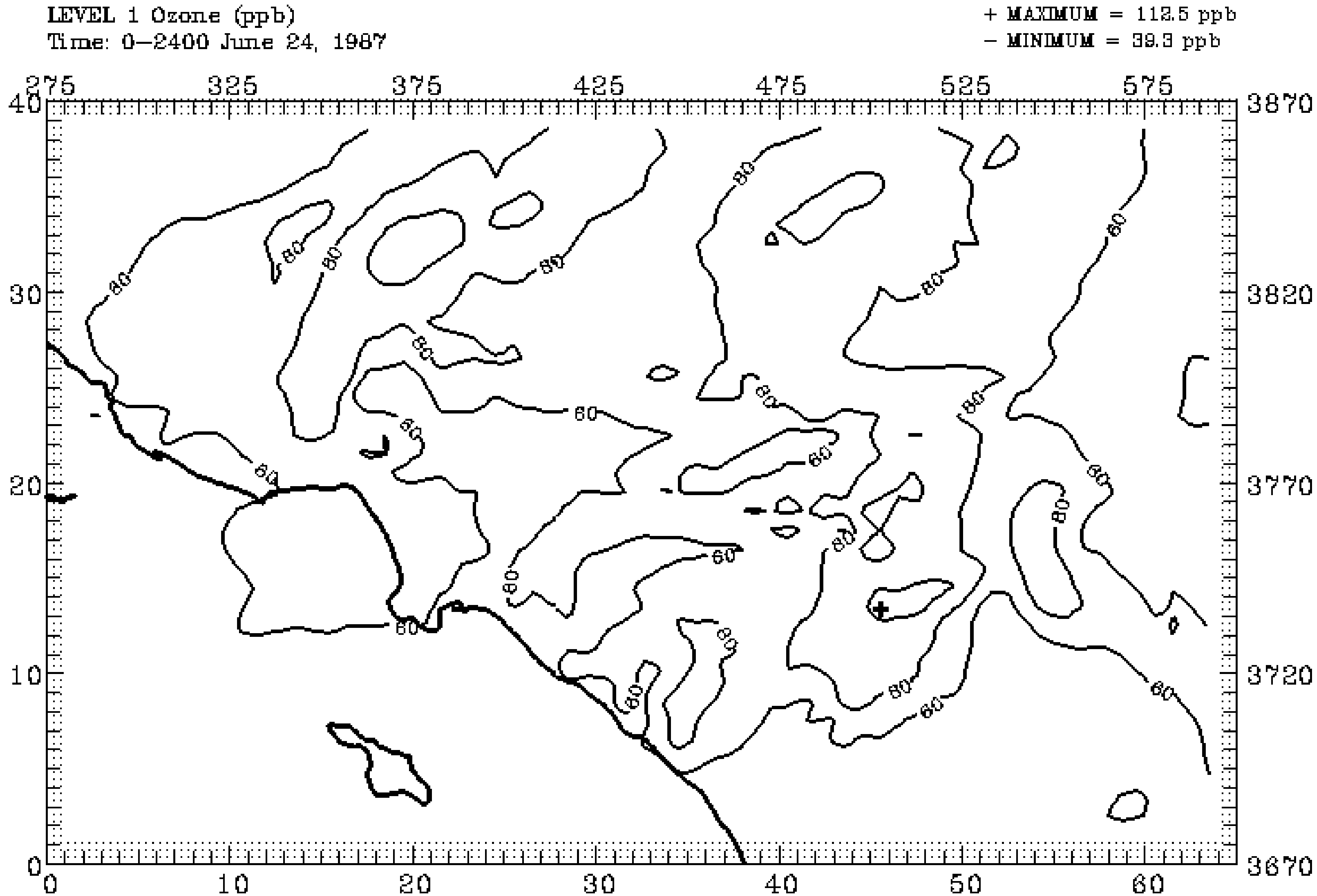


Figure 23b. Maximum simulated ozone concentrations for 50% VOC reduction with standard CB4 - June 24, 1987.

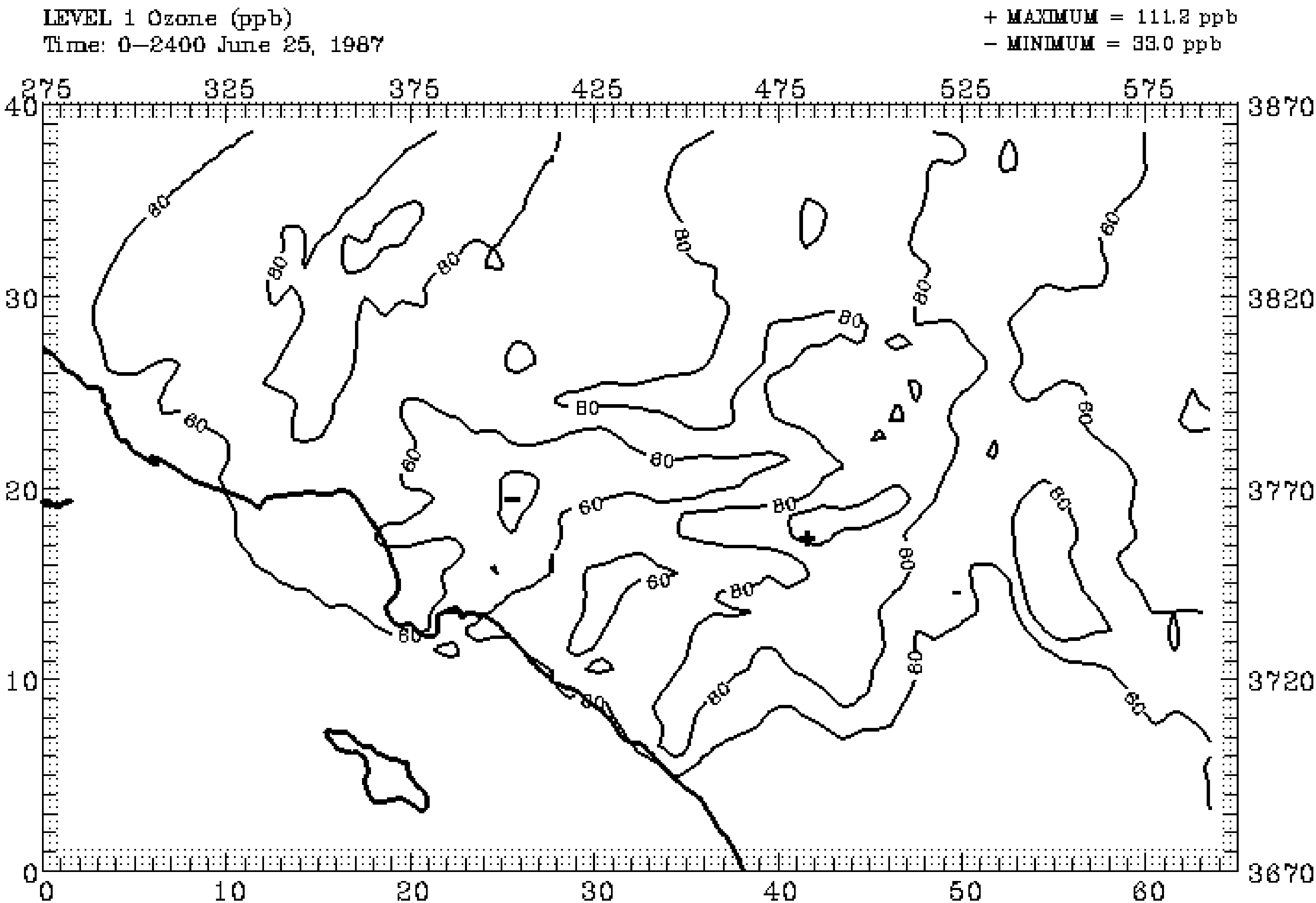


Figure 23c. Maximum simulated ozone concentrations for 50% VOC reduction with standard CB4 - June 25, 1987.

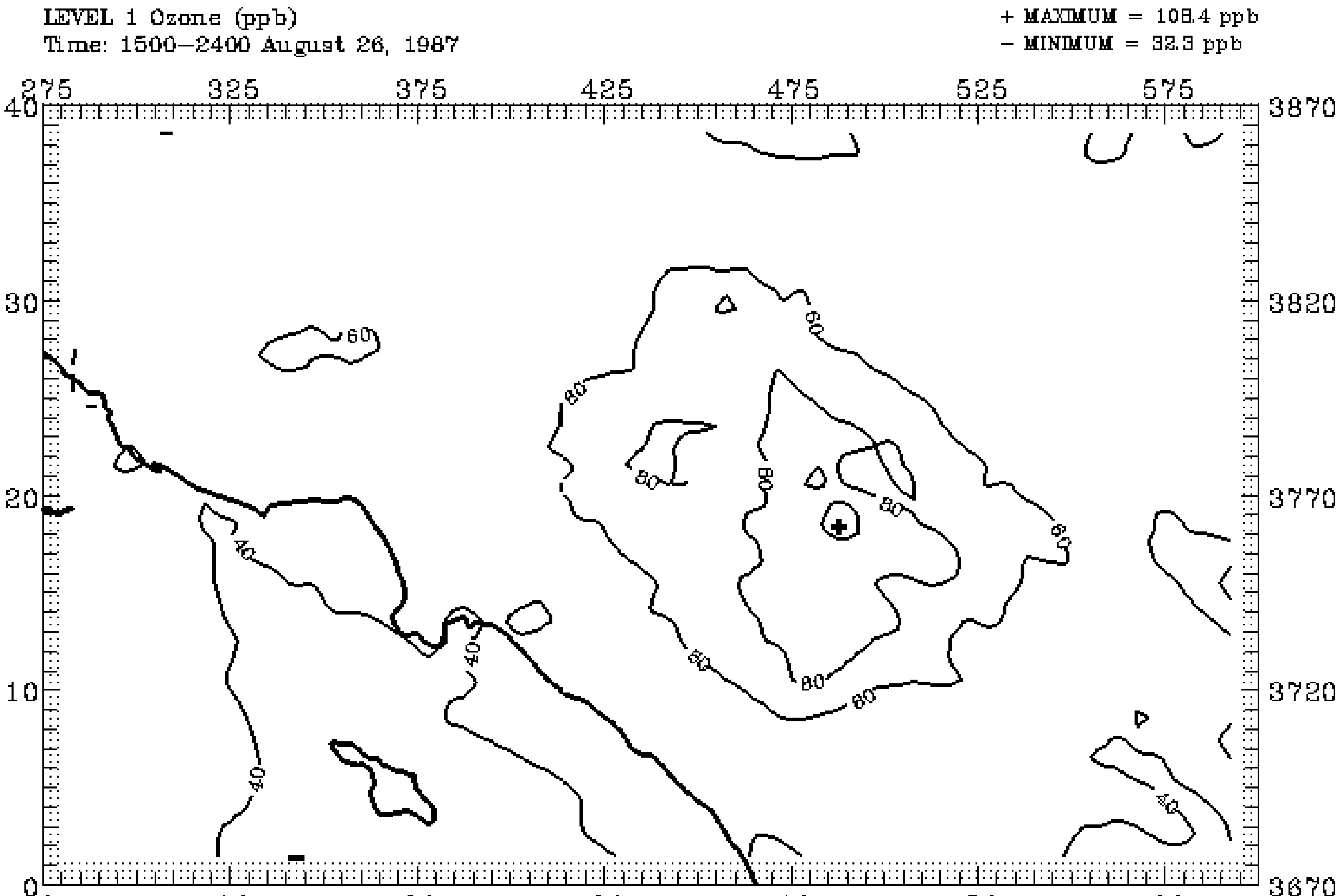


Figure 24a. Maximum simulated ozone concentrations for 50% VOC reduction with standard CB4 - August 26, 1987.

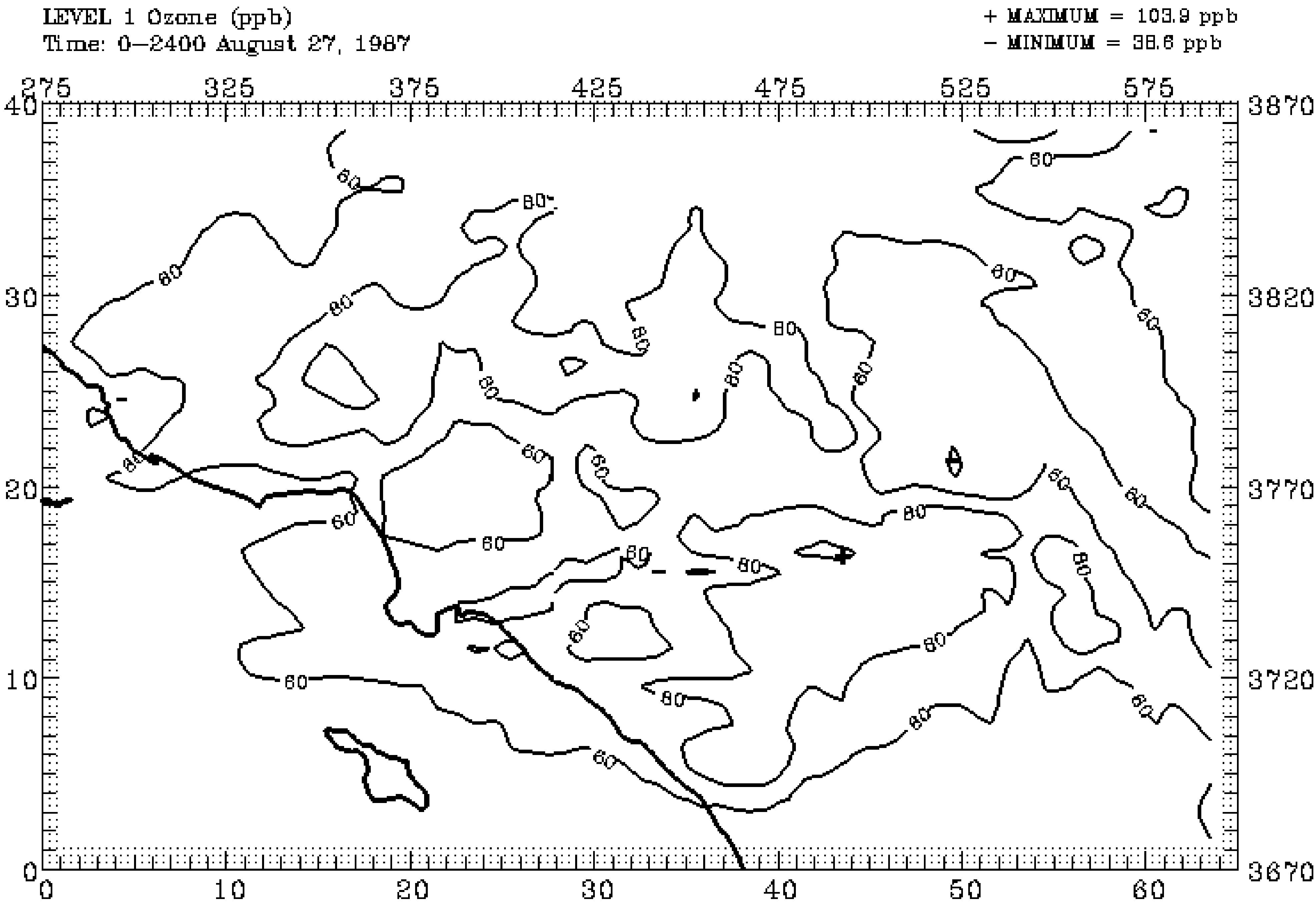


Figure 24b. Maximum simulated ozone concentrations for 50% VOC reduction with standard CB4 - August 27, 1987.

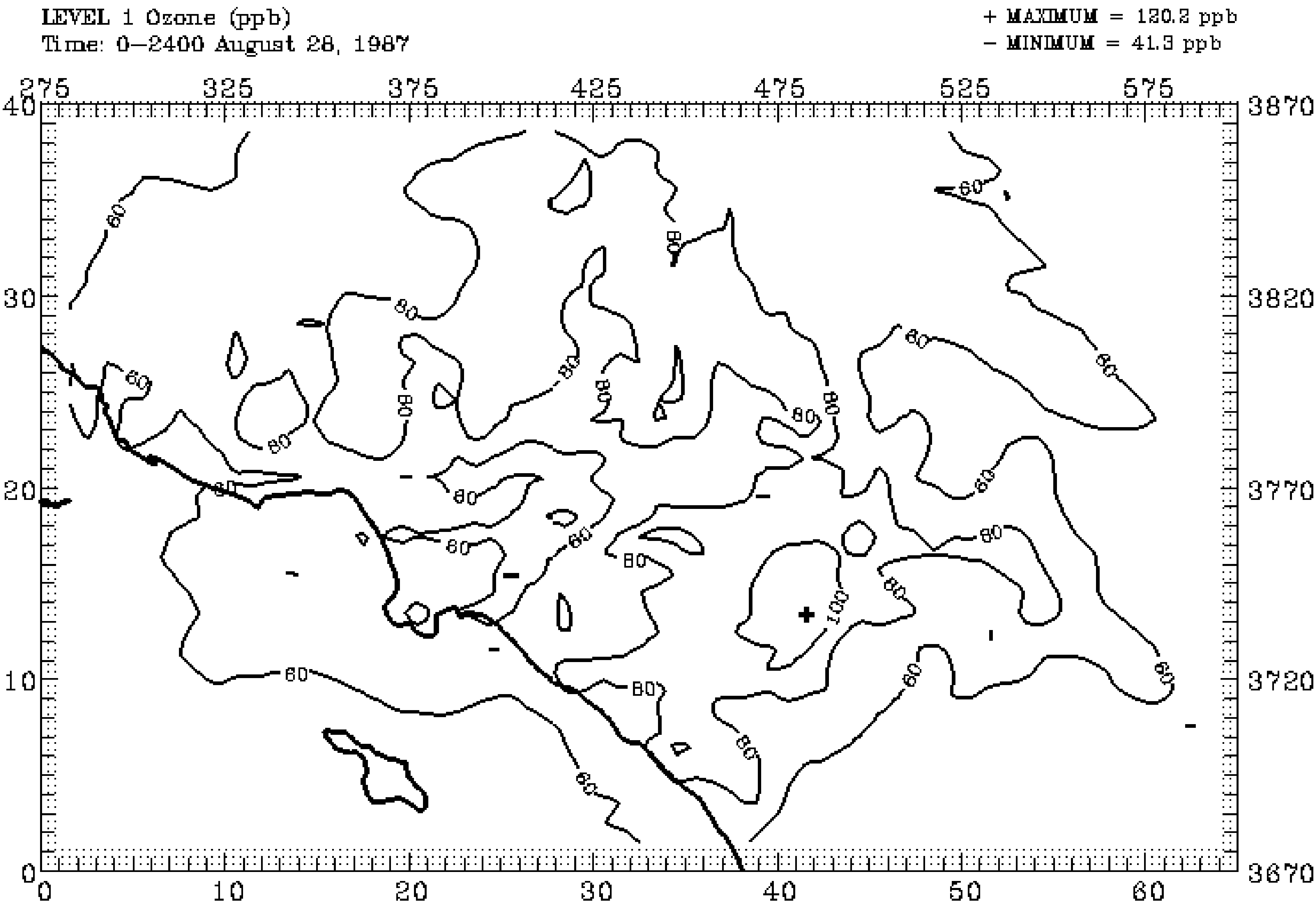


Figure 24c. Maximum simulated ozone concentrations for 50% VOC reduction with standard CB4 - August 28, 1987.

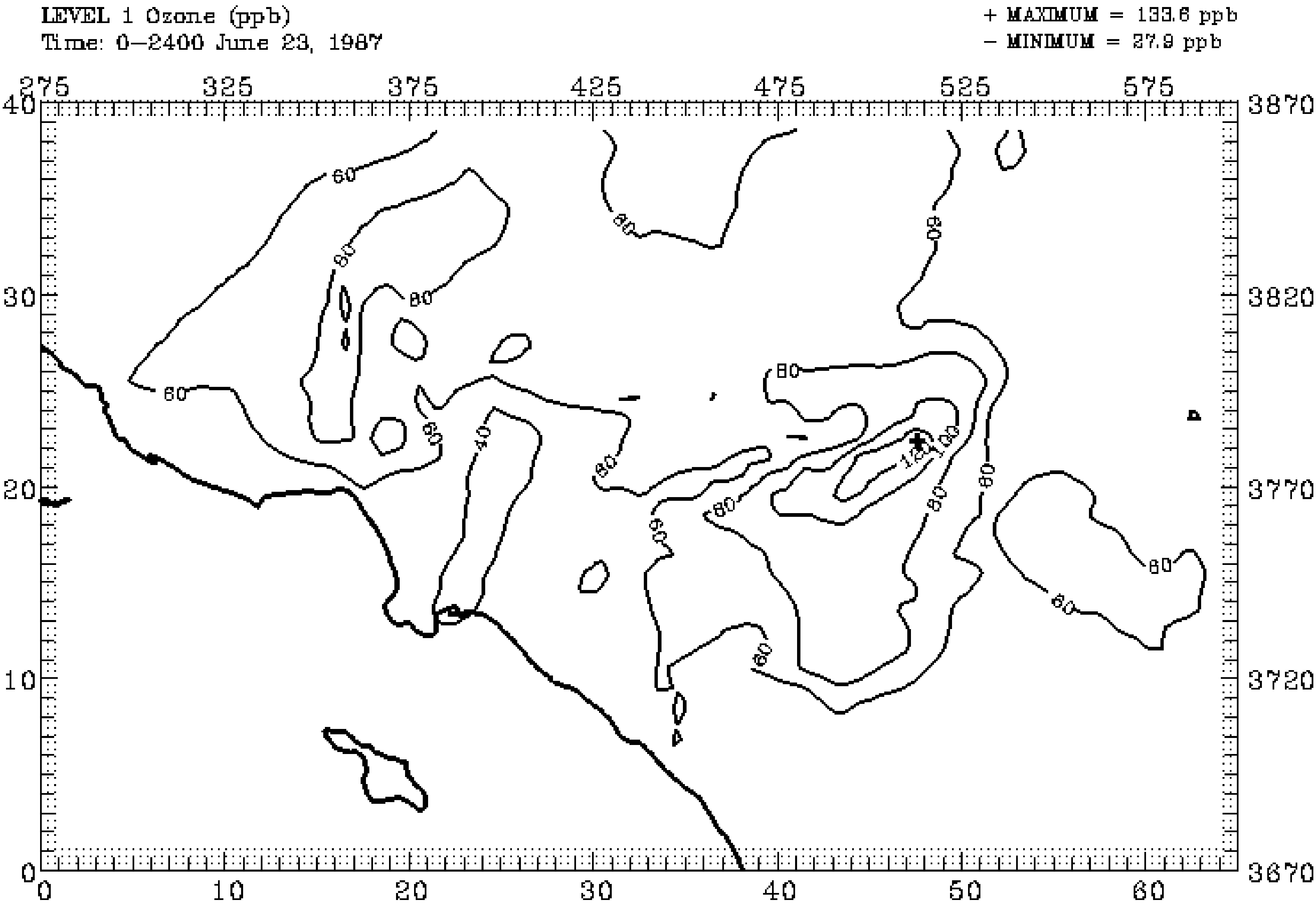


Figure 25a. Maximum simulated ozone concentrations for 50% VOC reduction with highflux CB4 - June 23, 1987.

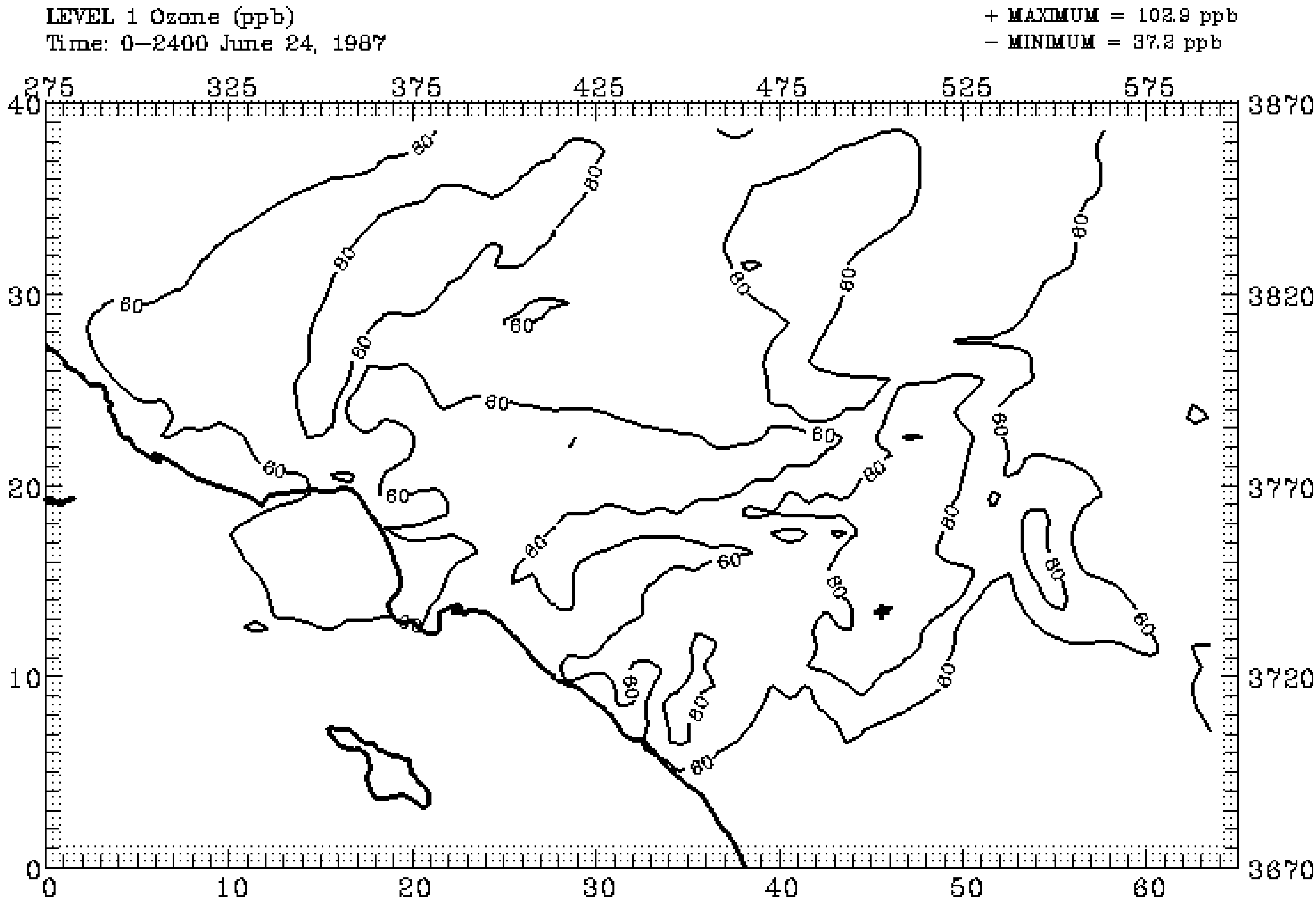


Figure 25b. Maximum simulated ozone concentrations for 50% VOC reduction with highflux CB4 - June 24, 1987.

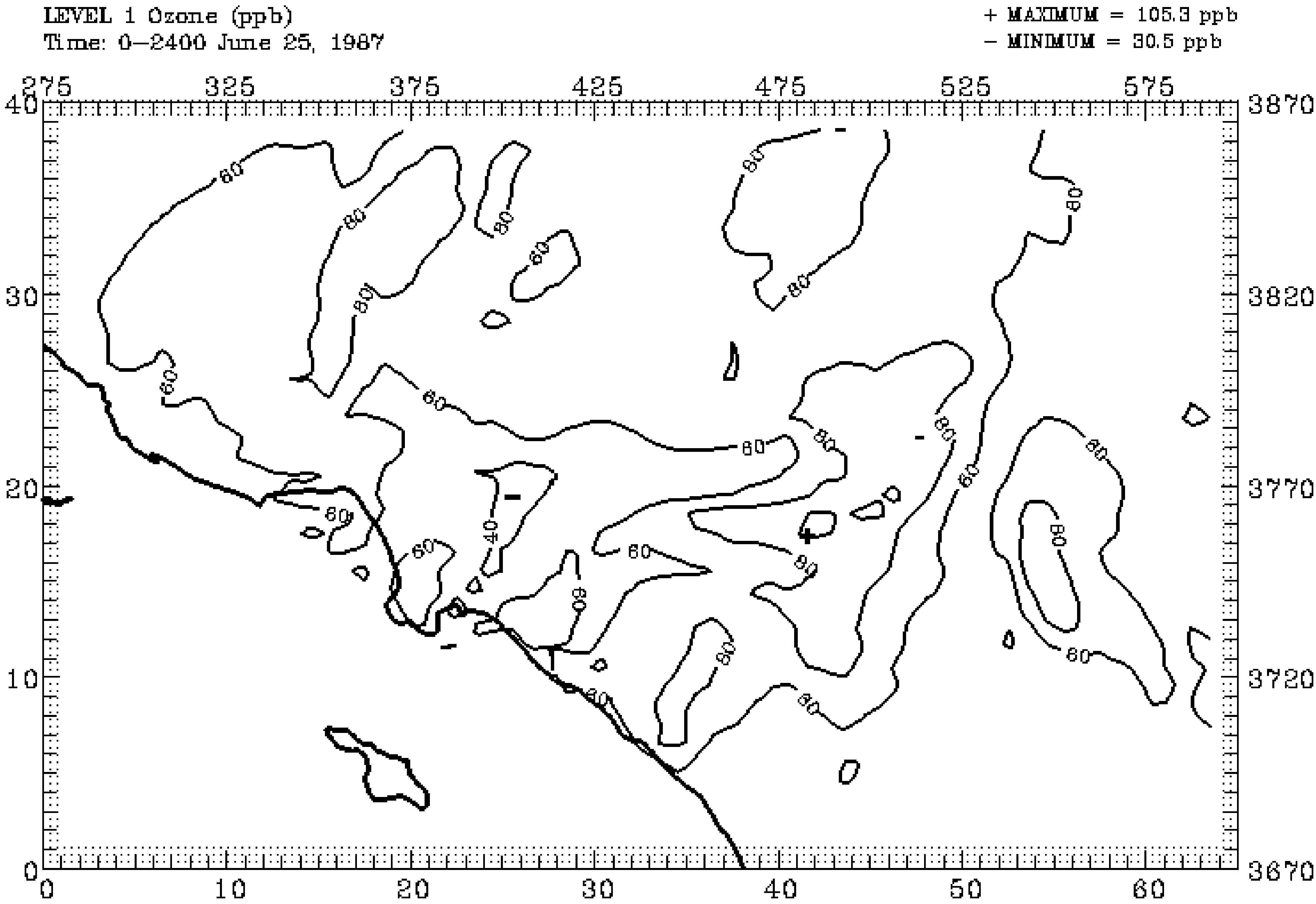


Figure 25c. Maximum simulated ozone concentrations for 50% VOC Reduction with highflux CB4 - June 25, 1987.

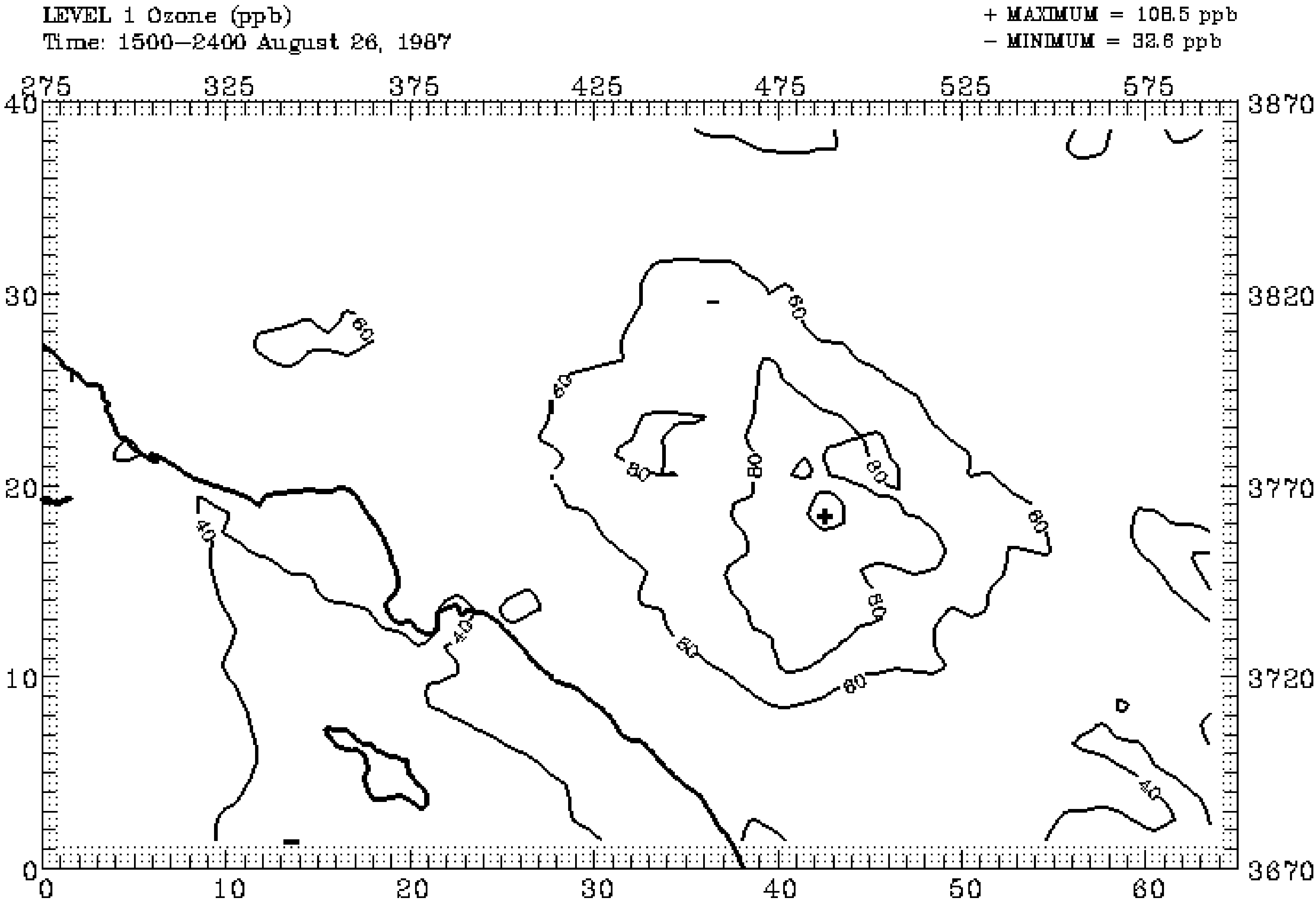


Figure 26a. Maximum simulated ozone concentrations for 50% VOC reduction with highflux CB4 - August 26, 1987.

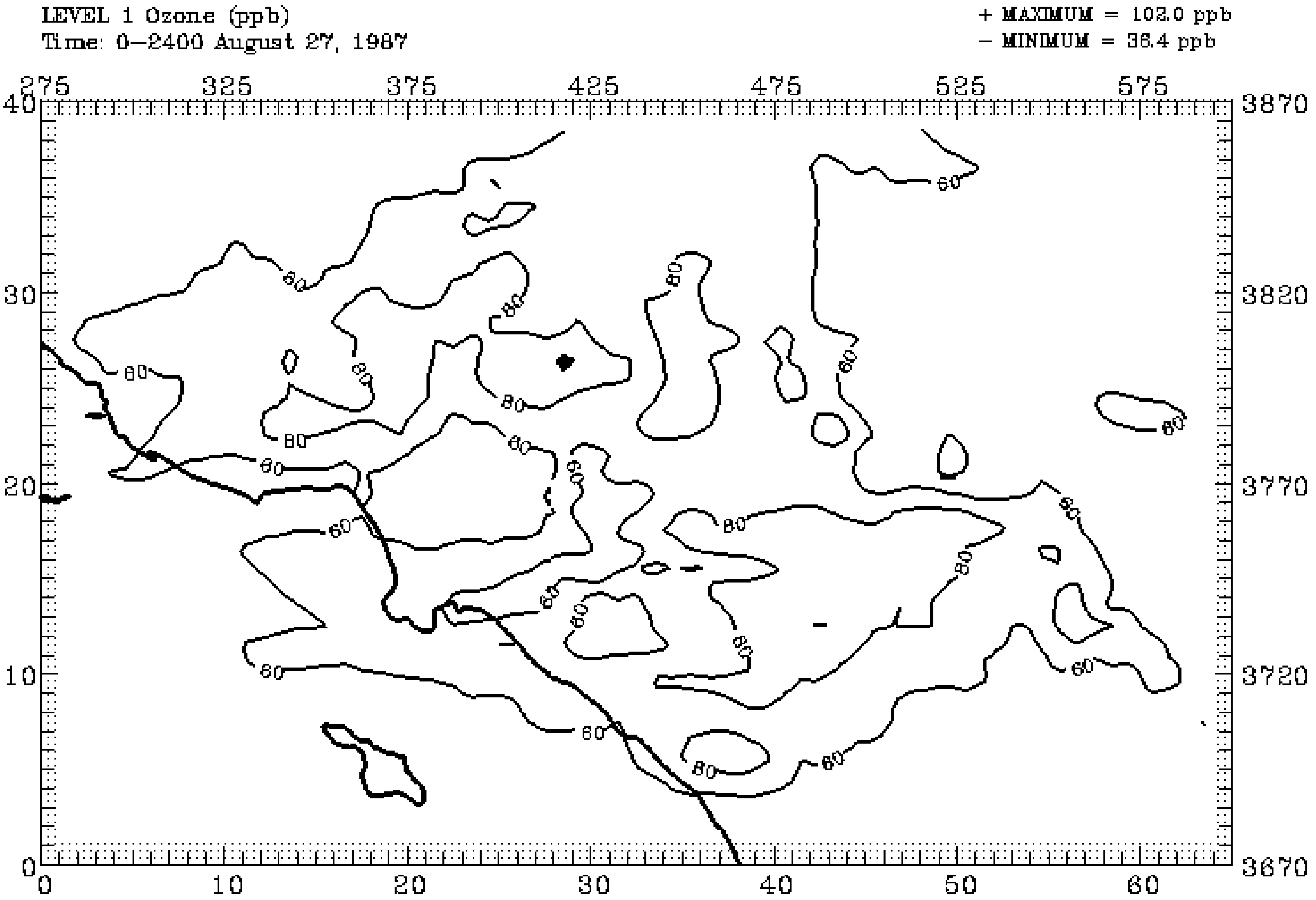


Figure 26b. Maximum simulated ozone concentrations for 50% VOC reduction with highflux CB4 - August 27, 1987.

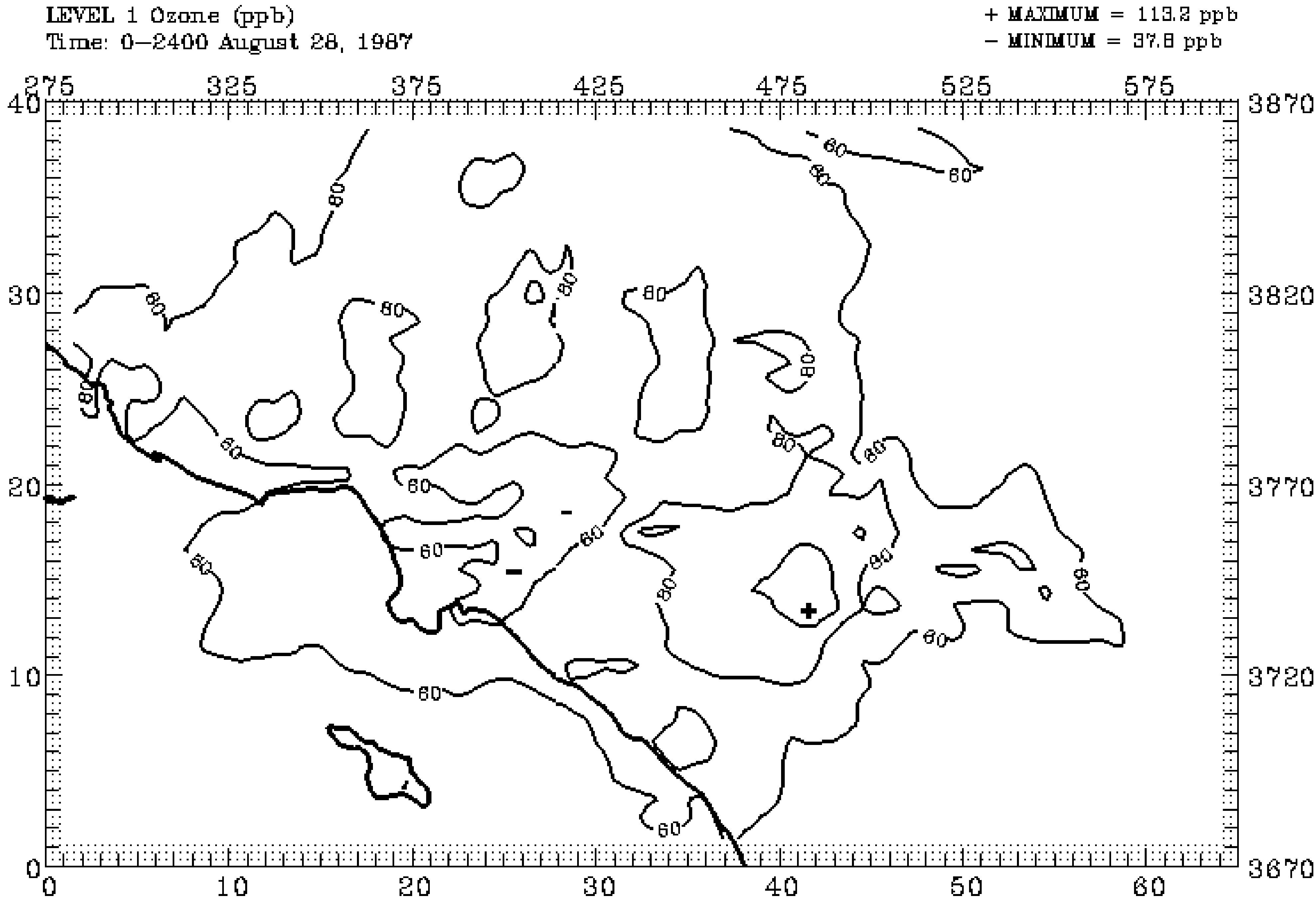


Figure 26c. Maximum simulated ozone concentrations for 50% VOC reduction with highflux CB4 - August 28, 1987.

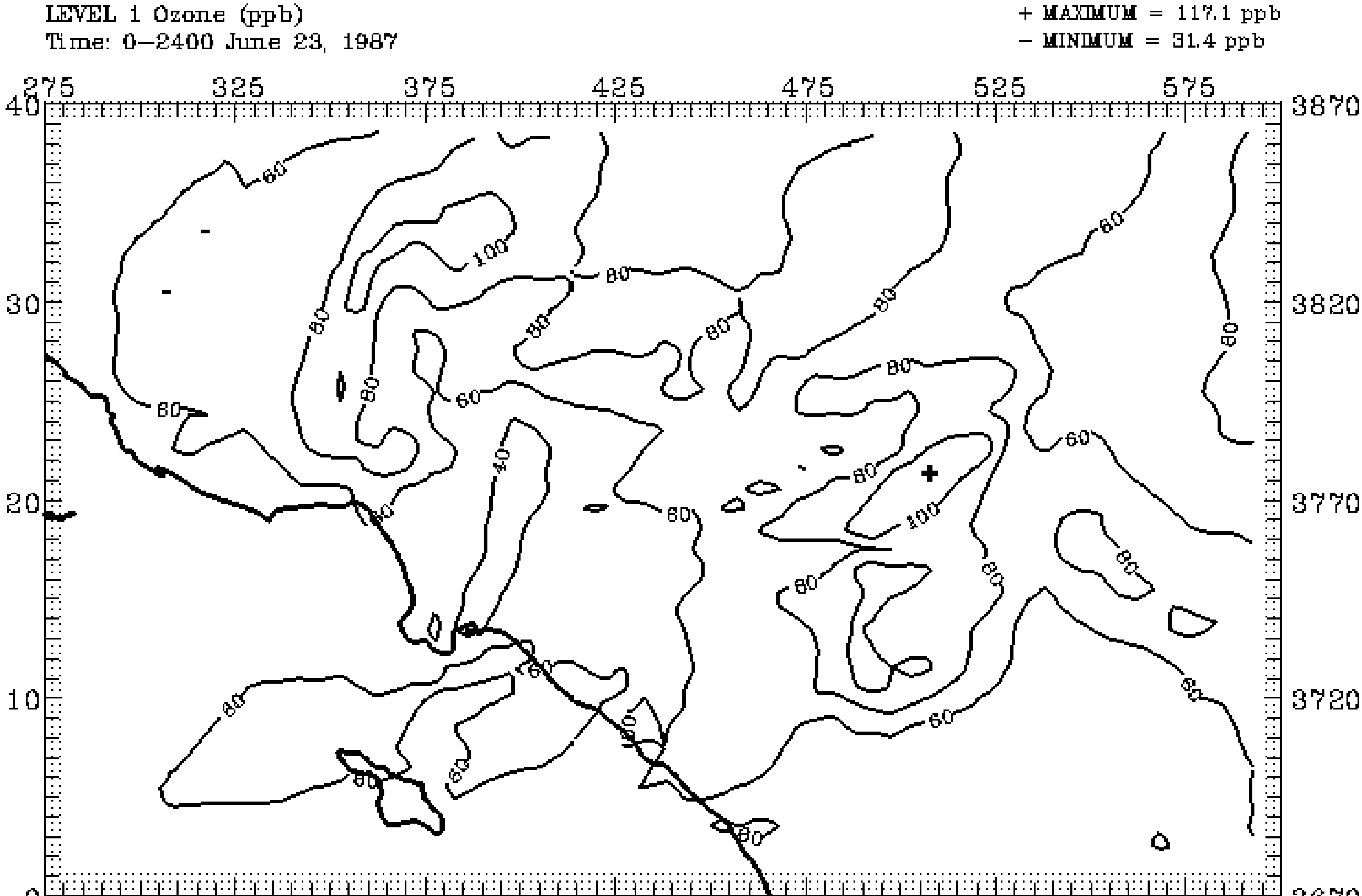


Figure 27a. Maximum simulated ozone concentrations for 50% VOC reduction with lowflux CB4 - June 23, 1987.

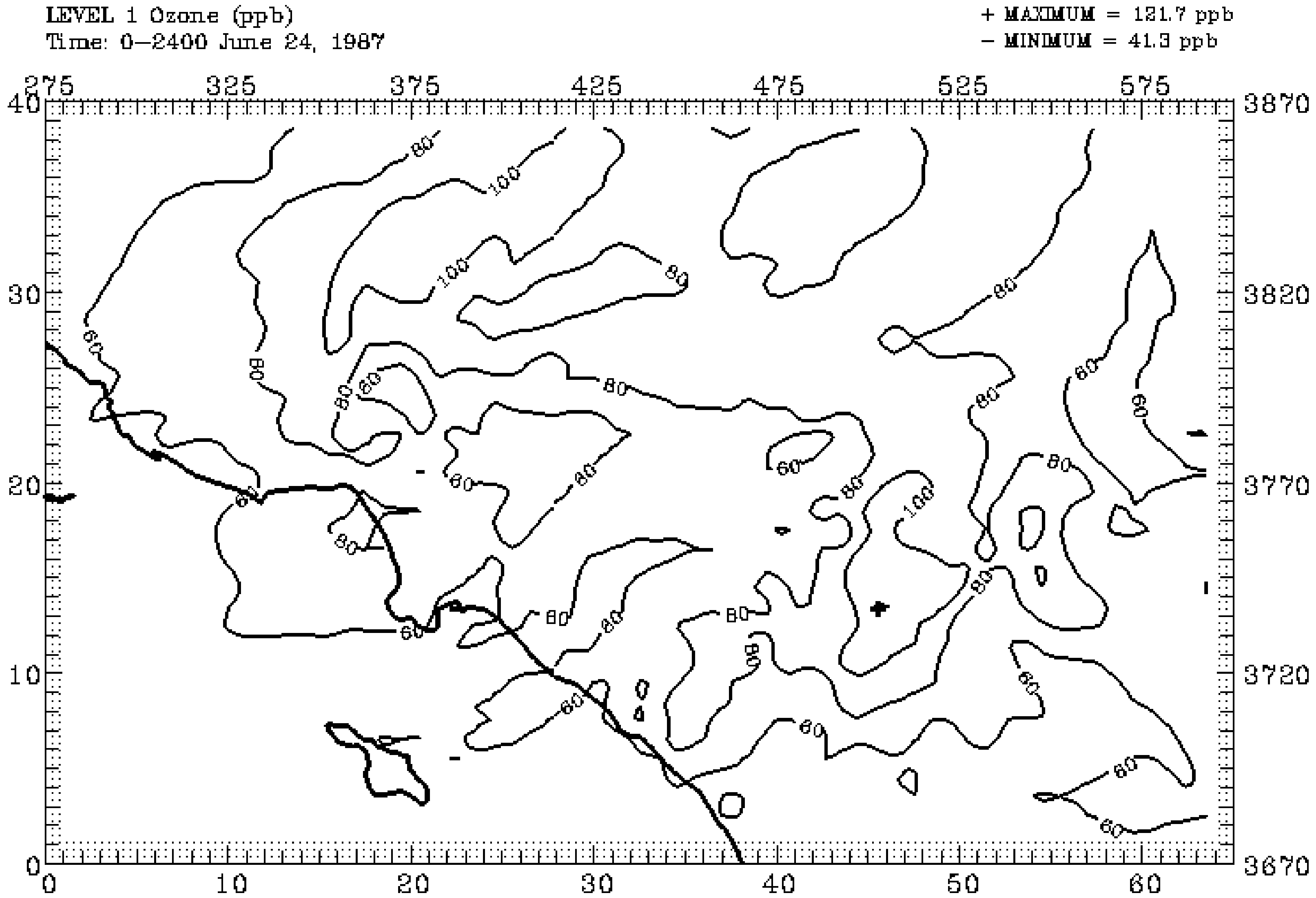


Figure 27b. Maximum simulated ozone concentrations for 50% VOC reduction with lowflux CB4 - June 24, 1987.

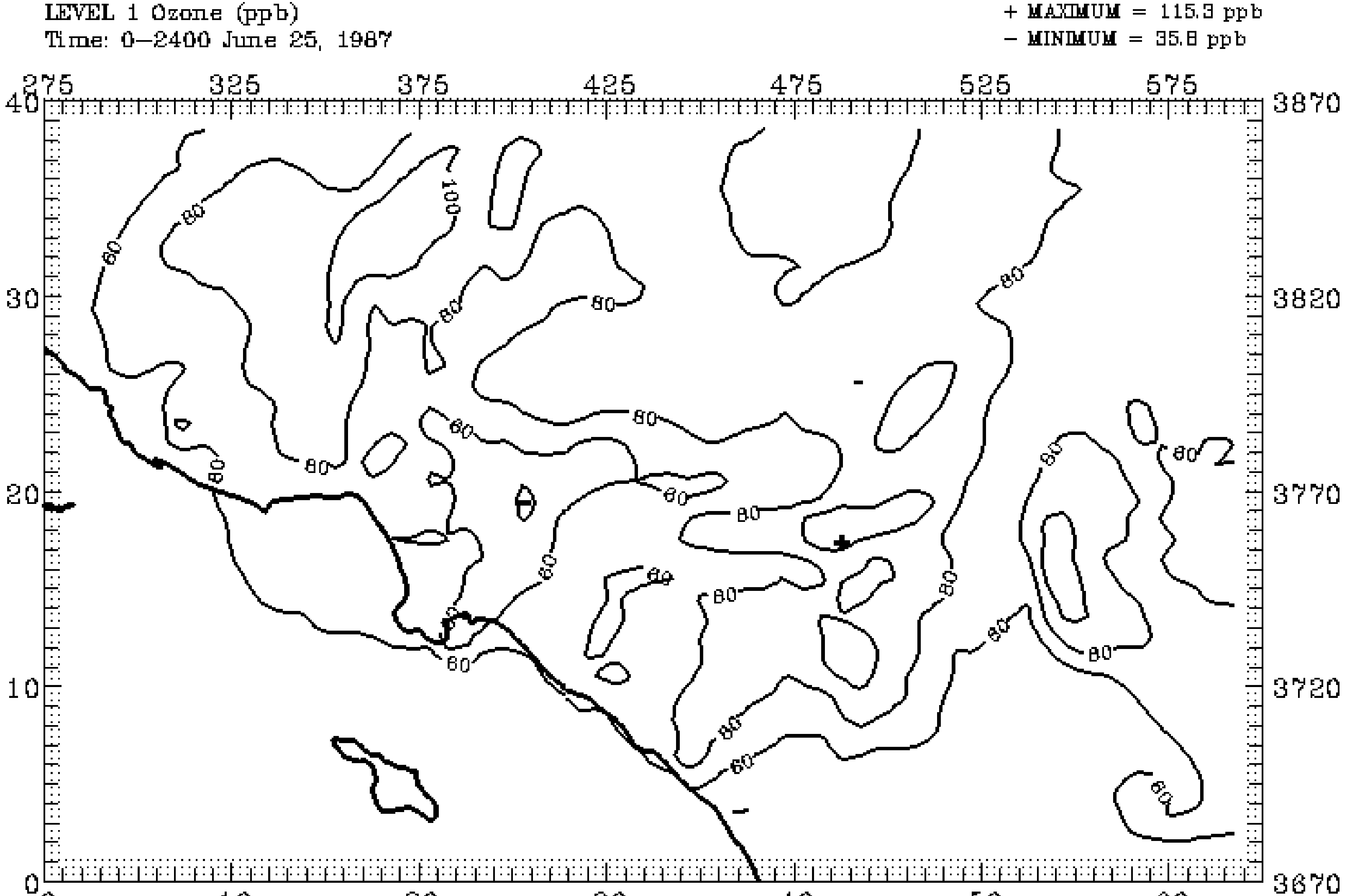


Figure 27c. Maximum simulated ozone concentrations for 50% VOC reduction with lowflux CB4 - June 25, 1987.

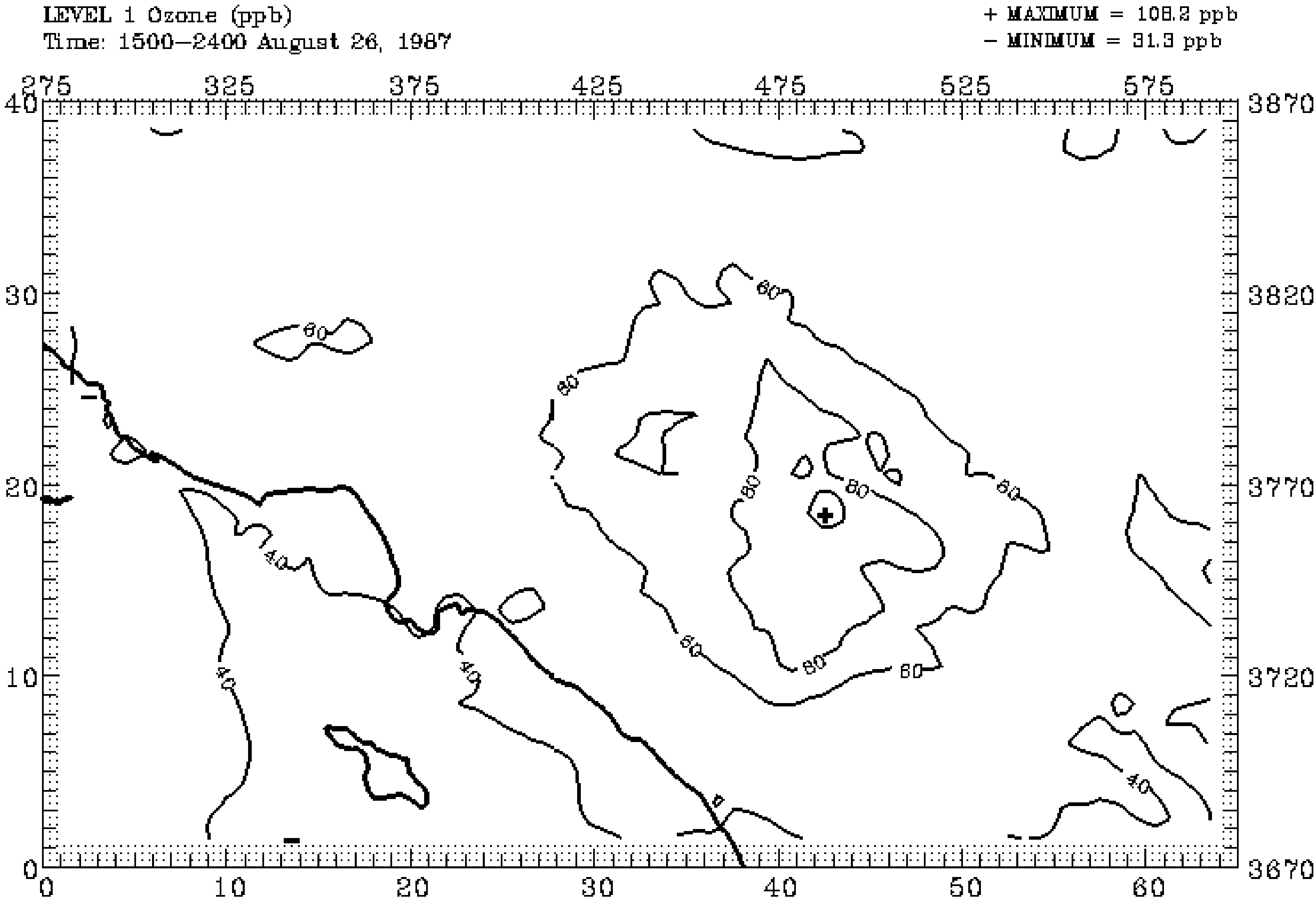


Figure 28a. Maximum simulated ozone concentrations for 50% VOC reduction with lowflux CB4 - August 26, 1987.

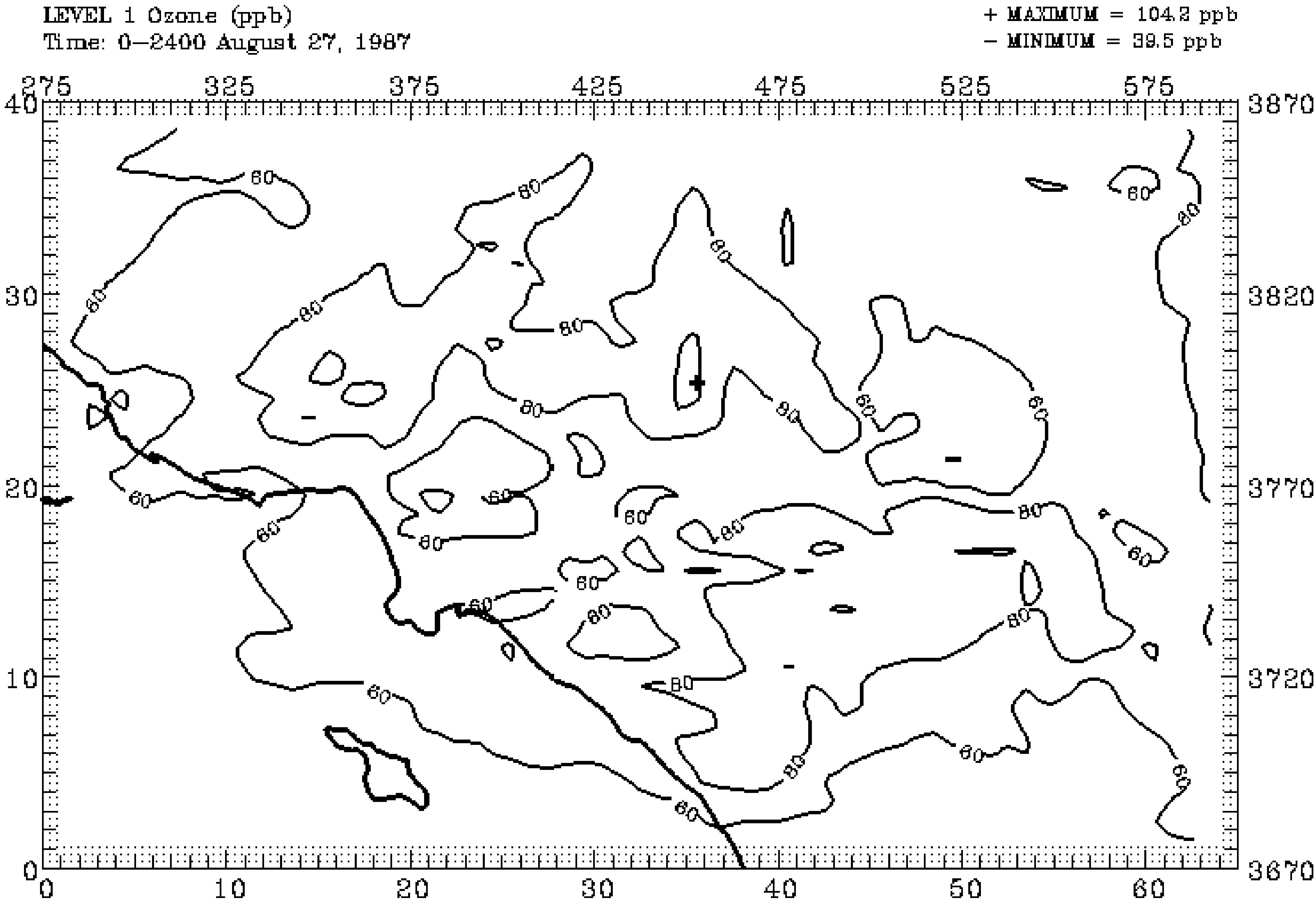


Figure 28b. Maximum simulated ozone concentrations for 50% VOC reduction with lowflux CB4 - August 27, 1987.

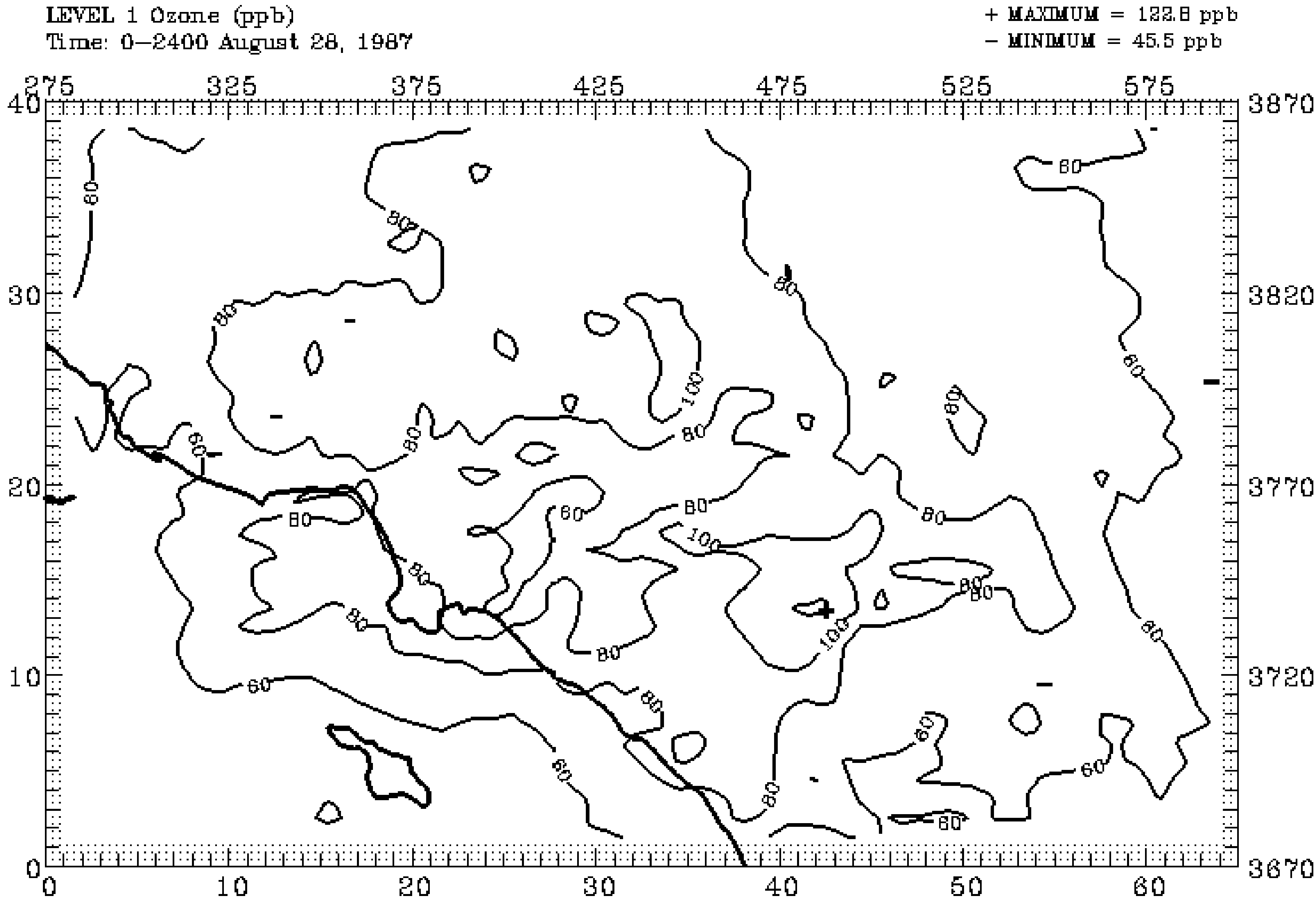


Figure 28c. Maximum simulated ozone concentrations for 50% VOC reduction with lowflux CB4 - August 28, 1987.

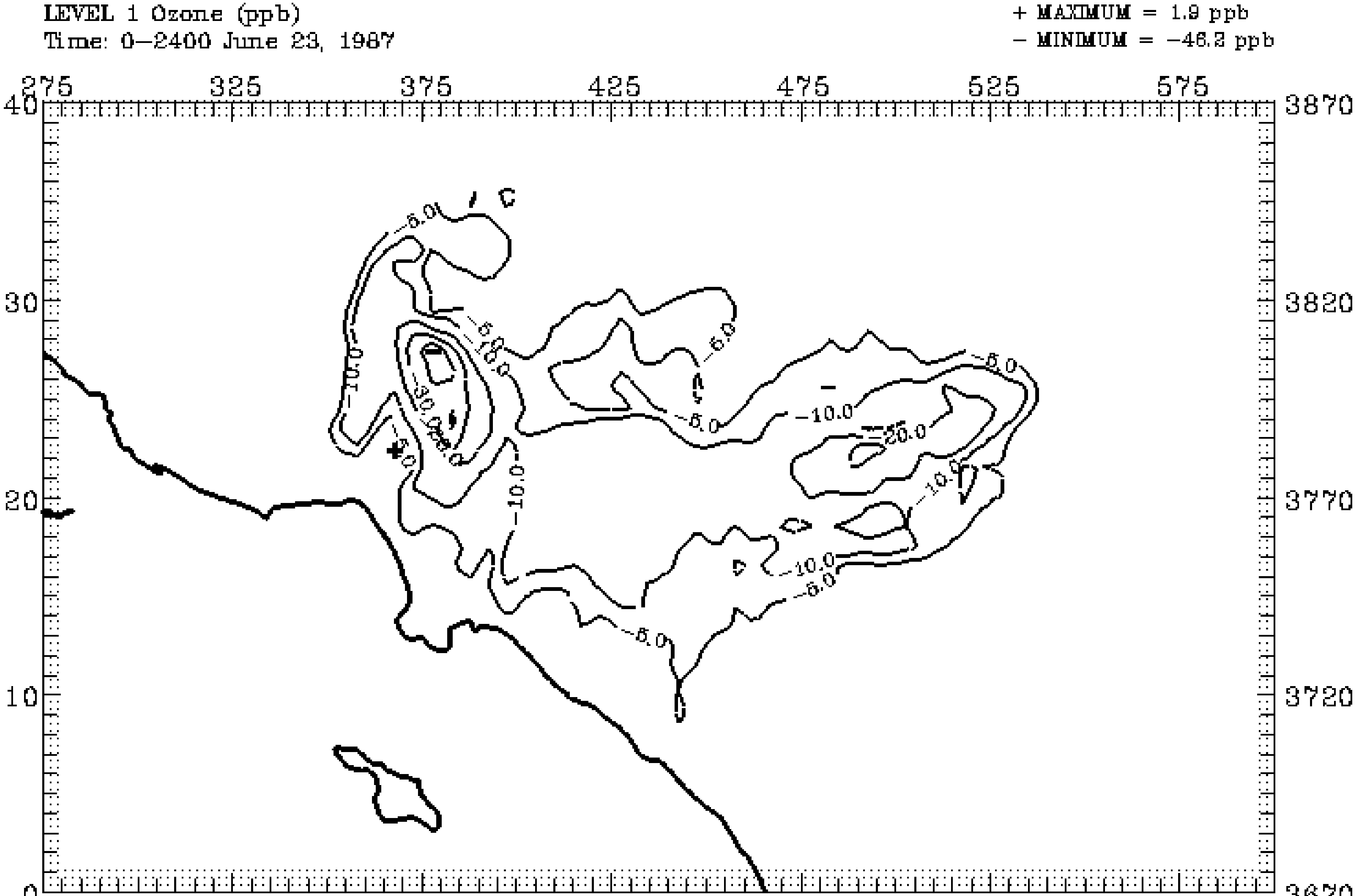


Figure 29a. Difference in maximum simulated ozone concentrations between VOC control run and base year run with standard CB4 - June 23, 1987.

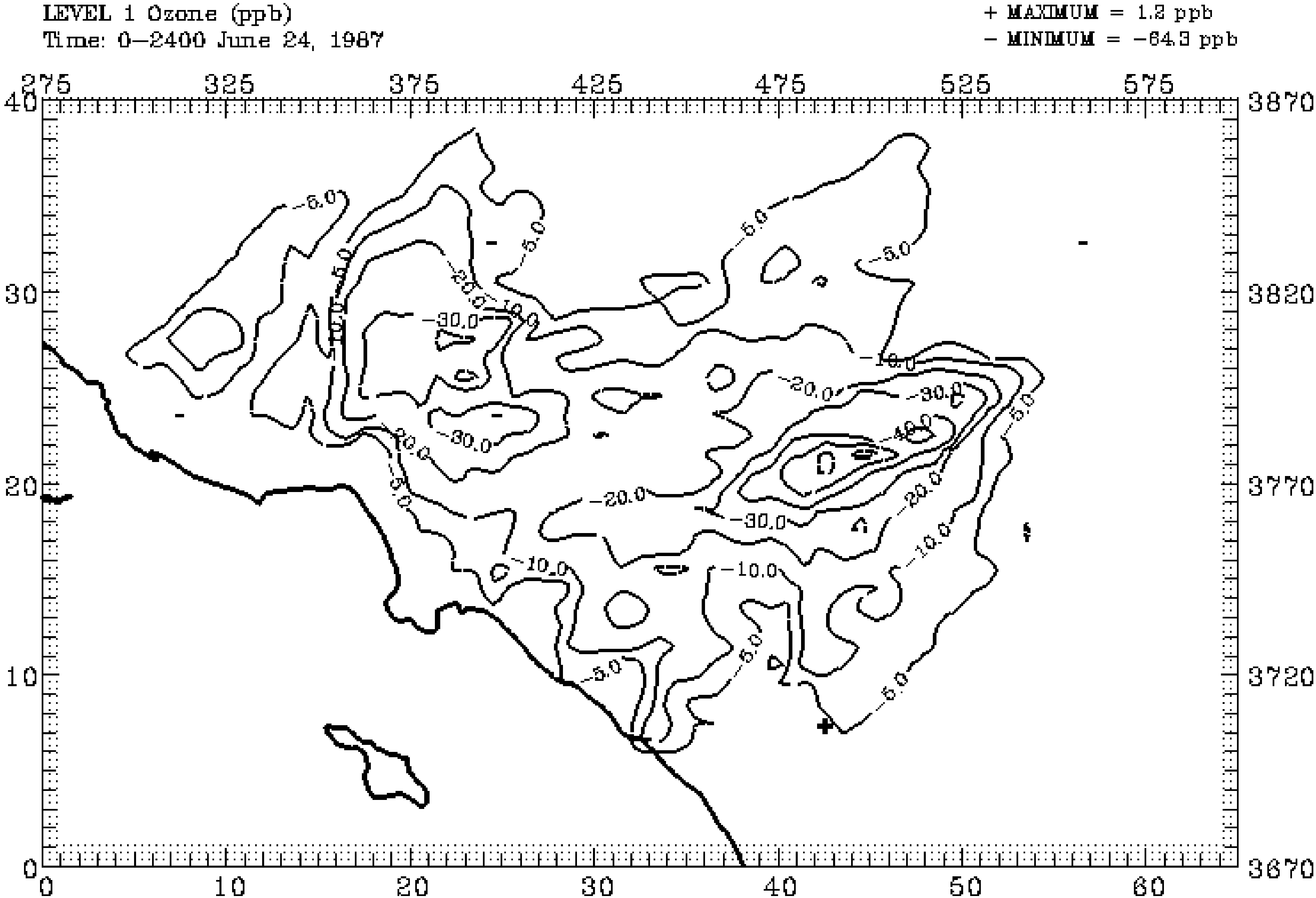


Figure 29b. Difference in maximum simulated ozone concentrations between VOC control run and base year run with standard CB4 - June 24, 1987.

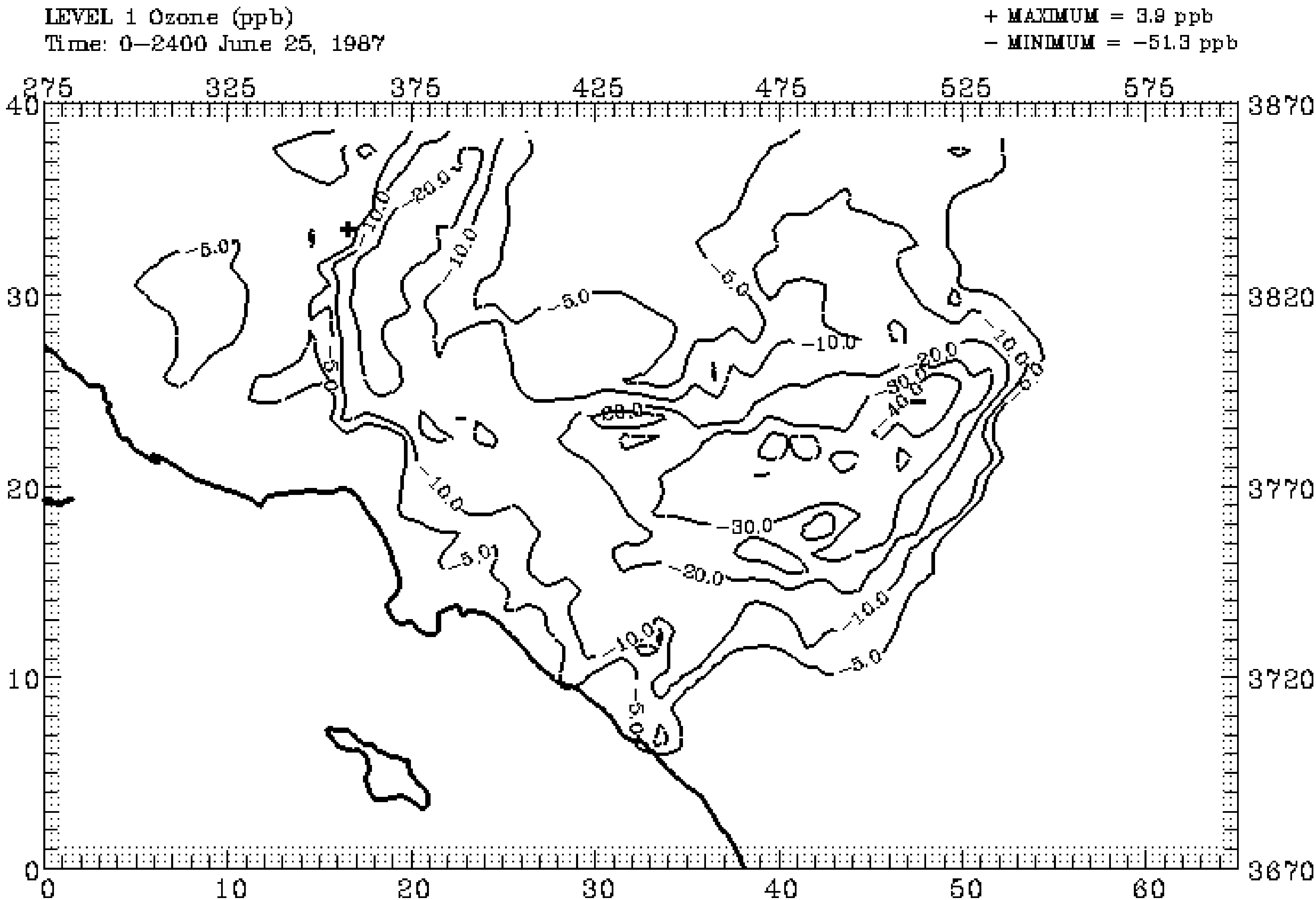


Figure 29c. Difference in maximum simulated ozone concentrations between VOC control run and base year run with standard CB4 - June 25, 1987.

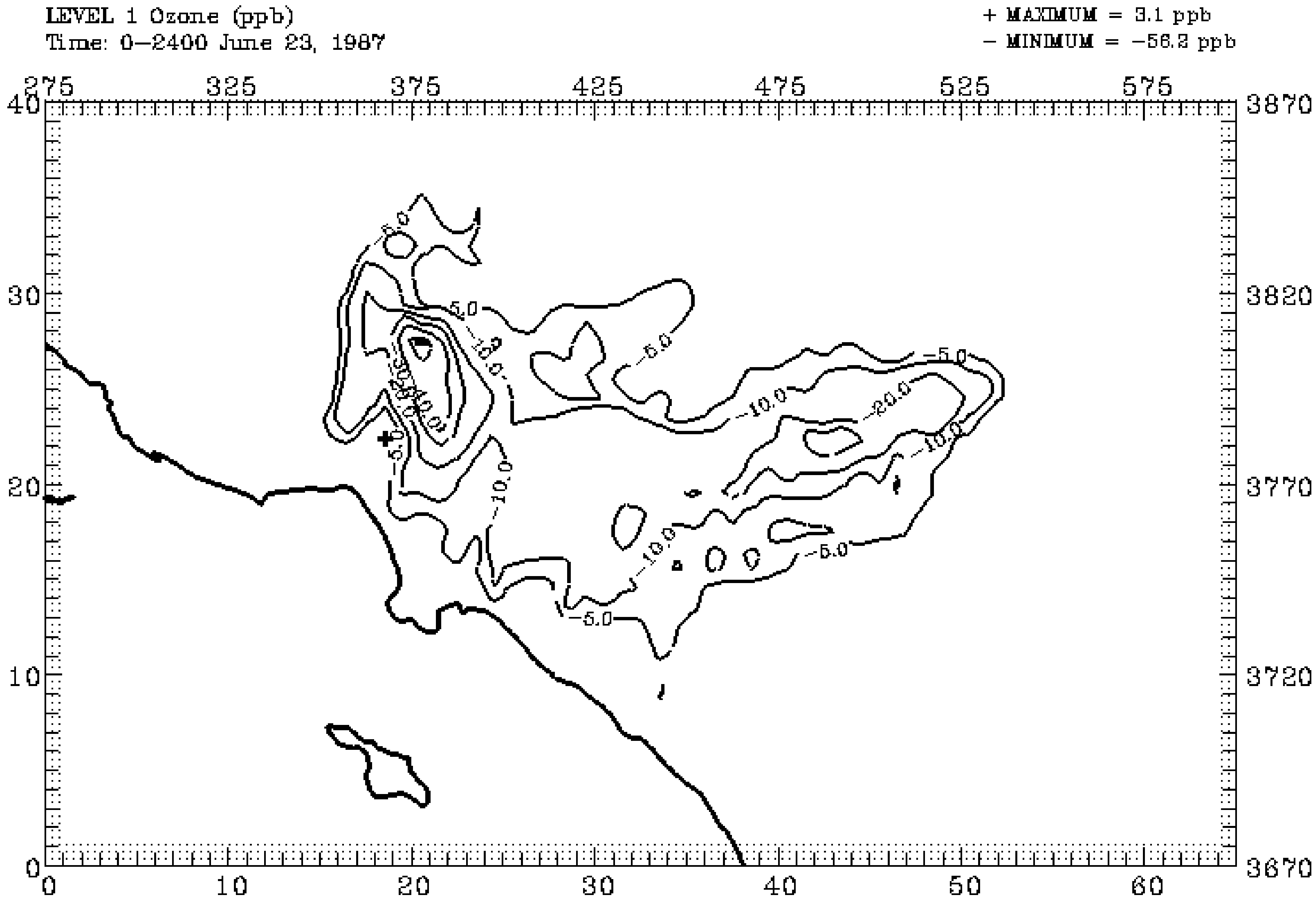


Figure 30a. Difference in maximum simulated ozone concentrations between VOC control run and base year run with highflux CB4 - June 23, 1987.

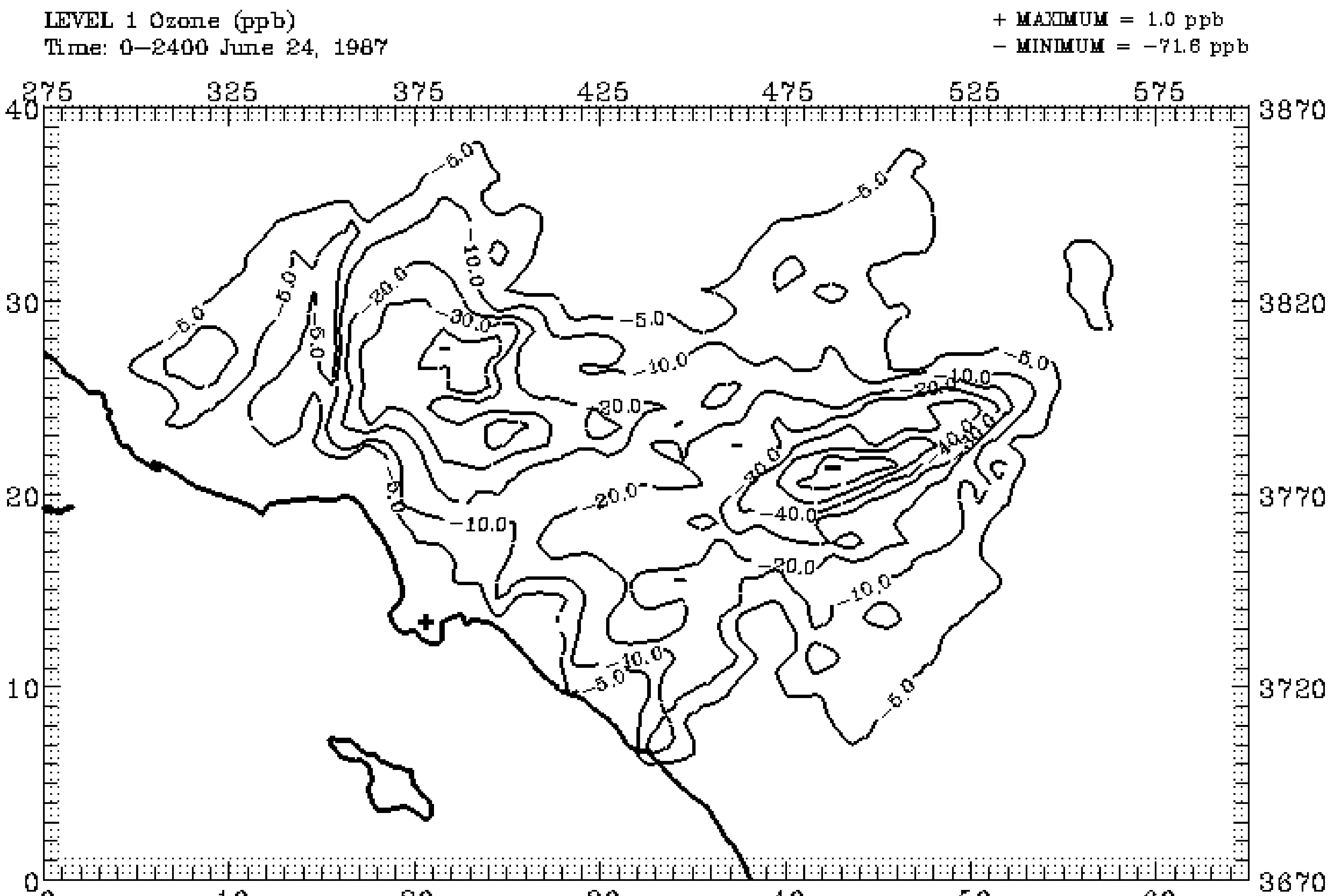


Figure 30b. Difference in maximum simulated ozone concentrations between VOC control run and base year run with highflux CB4 - June 24, 1987.

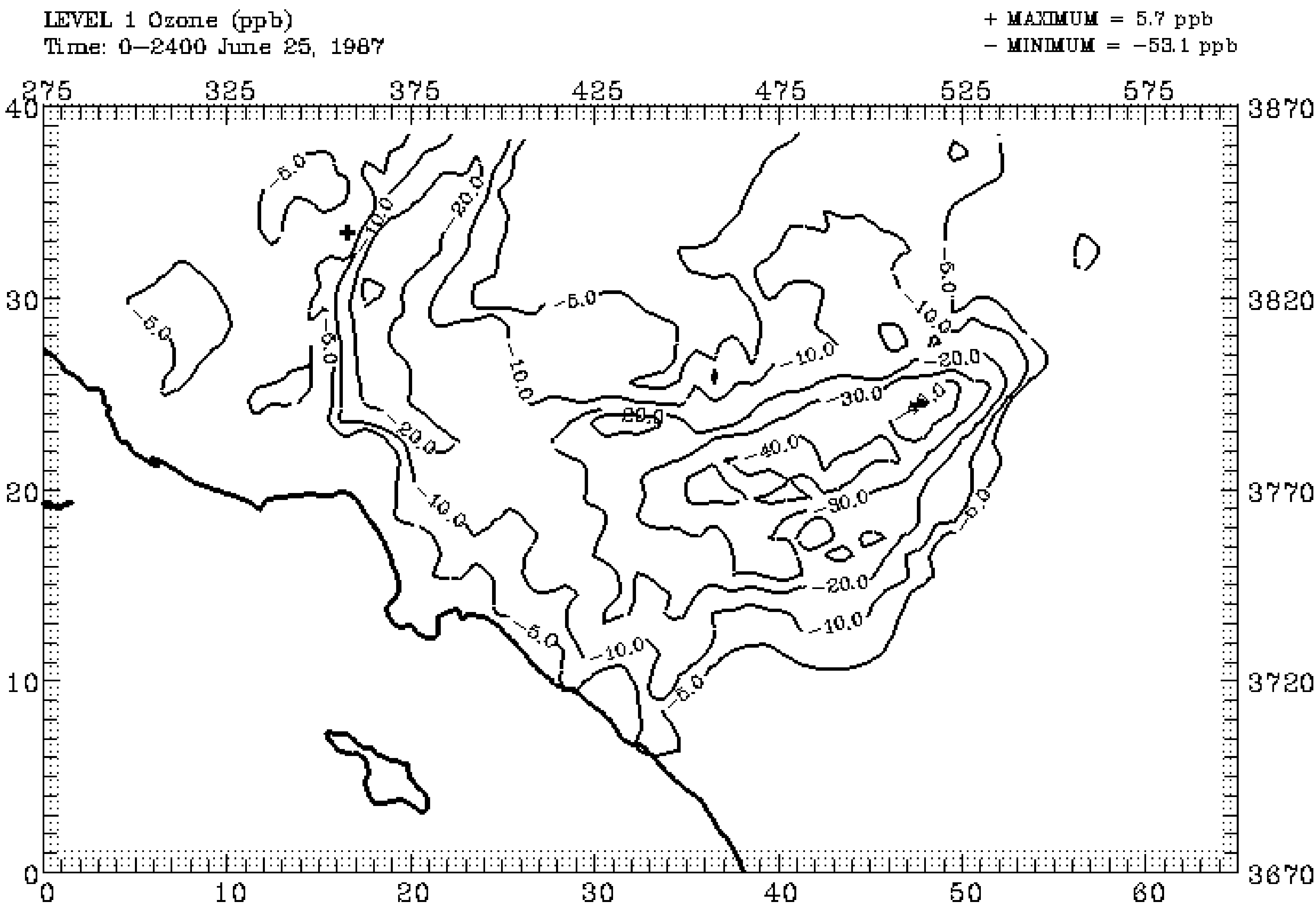


Figure 30c. Difference in maximum simulated ozone concentrations between VOC control run and base year run with highflux CB4 - June 25, 1987.

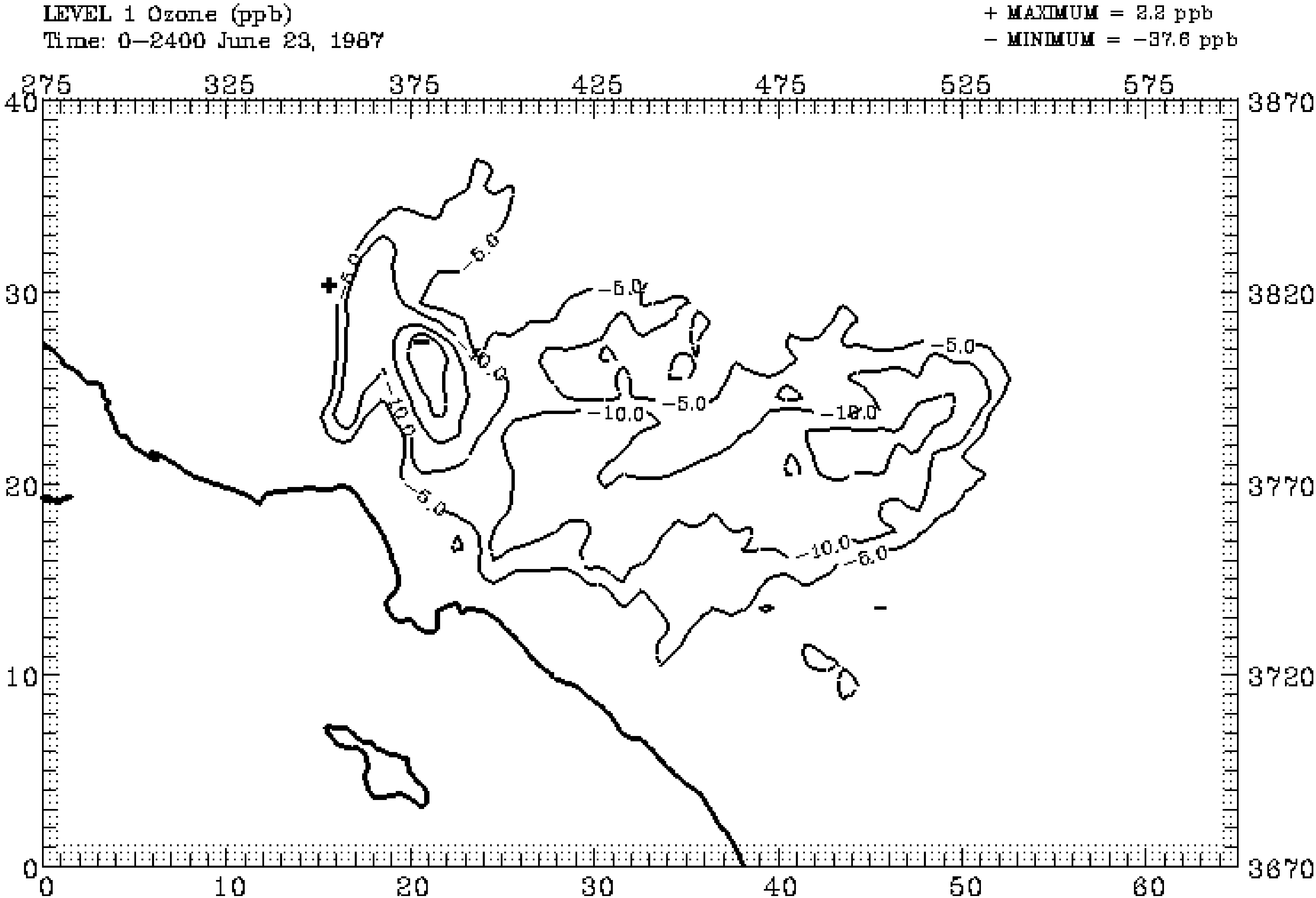


Figure 31a. Difference in maximum simulated ozone concentrations between VOC control run and base year run with lowflux CB4 - June 23, 1987.

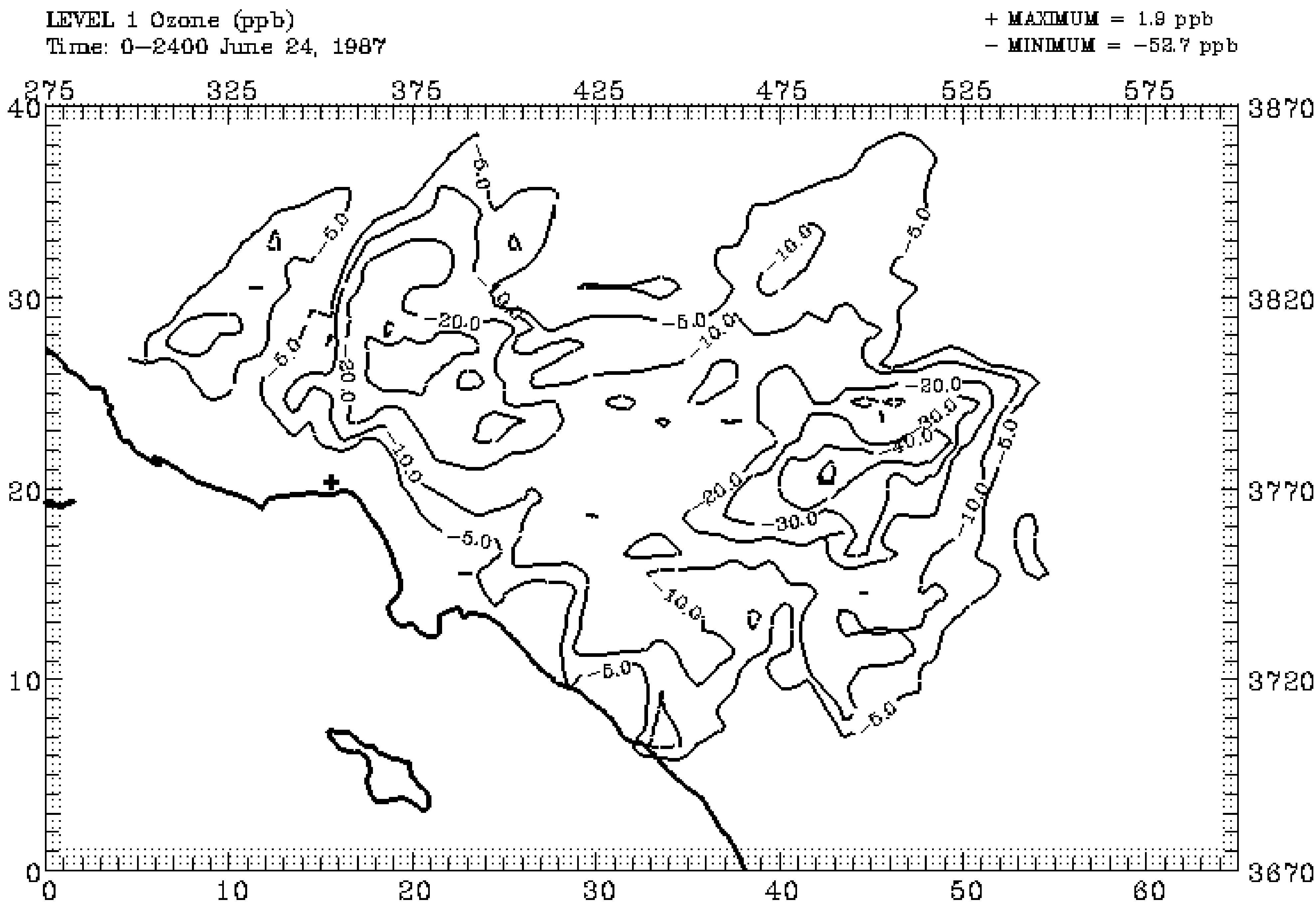


Figure 31b. Difference in maximum simulated ozone concentrations between VOC control run and base year run with lowflux CB4 - June 24, 1987.

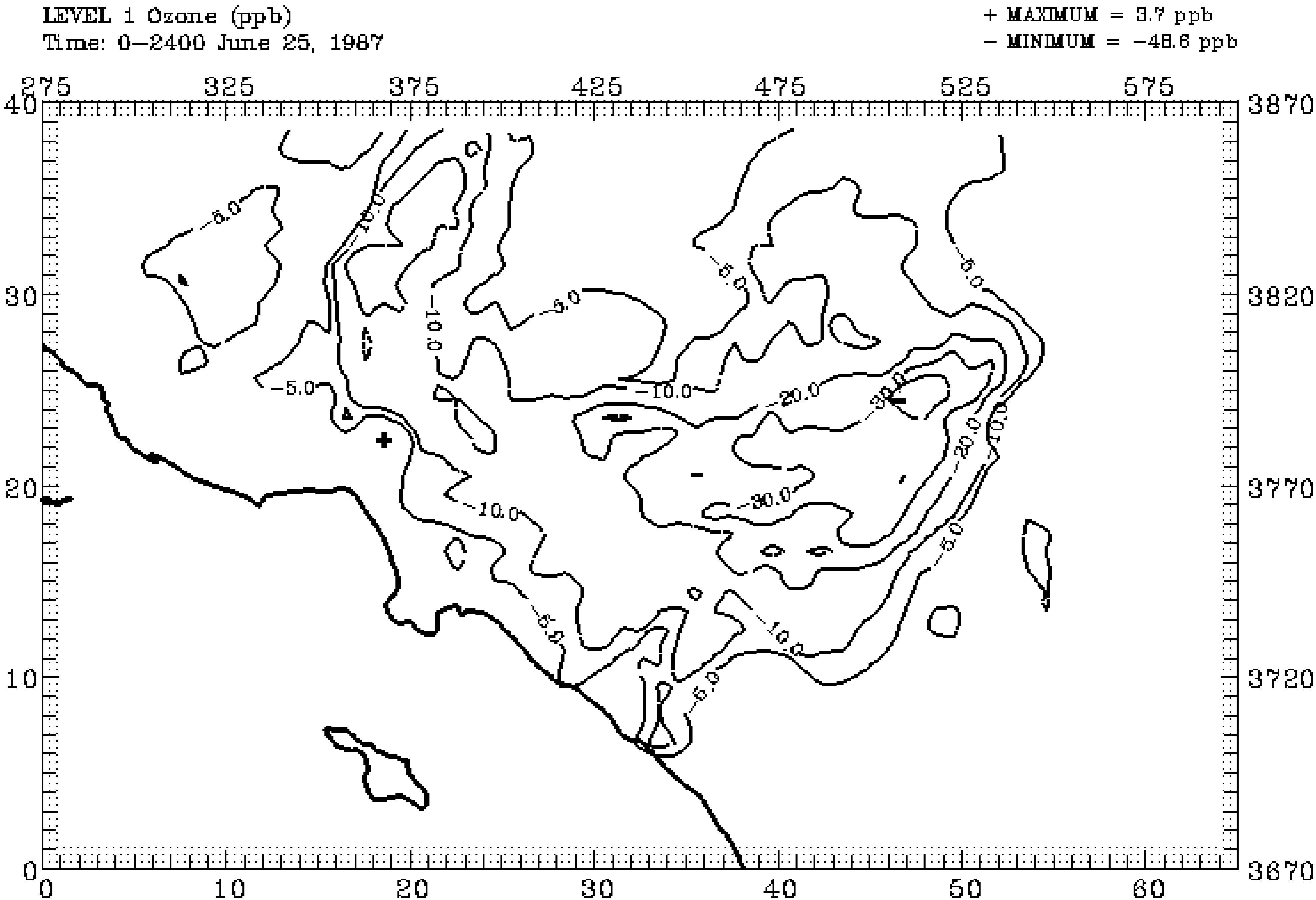


Figure 31c. Difference in maximum simulated ozone concentrations between VOC control run and base year run with lowflux CB4 - June 25, 1987.

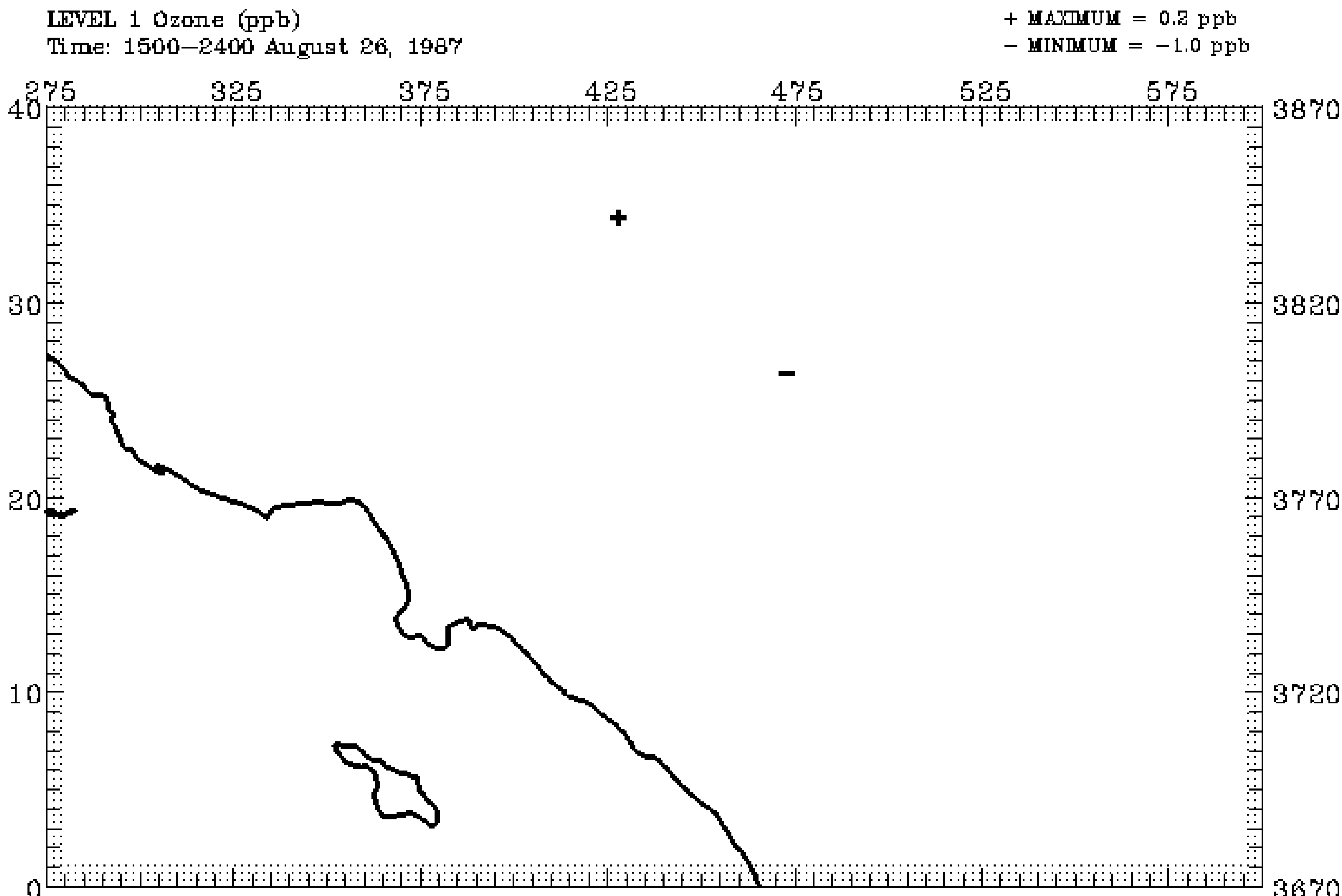


Figure 32a. Difference in maximum simulated ozone concentrations between VOC control run and base year run with standard CB4 - August 26, 1987.

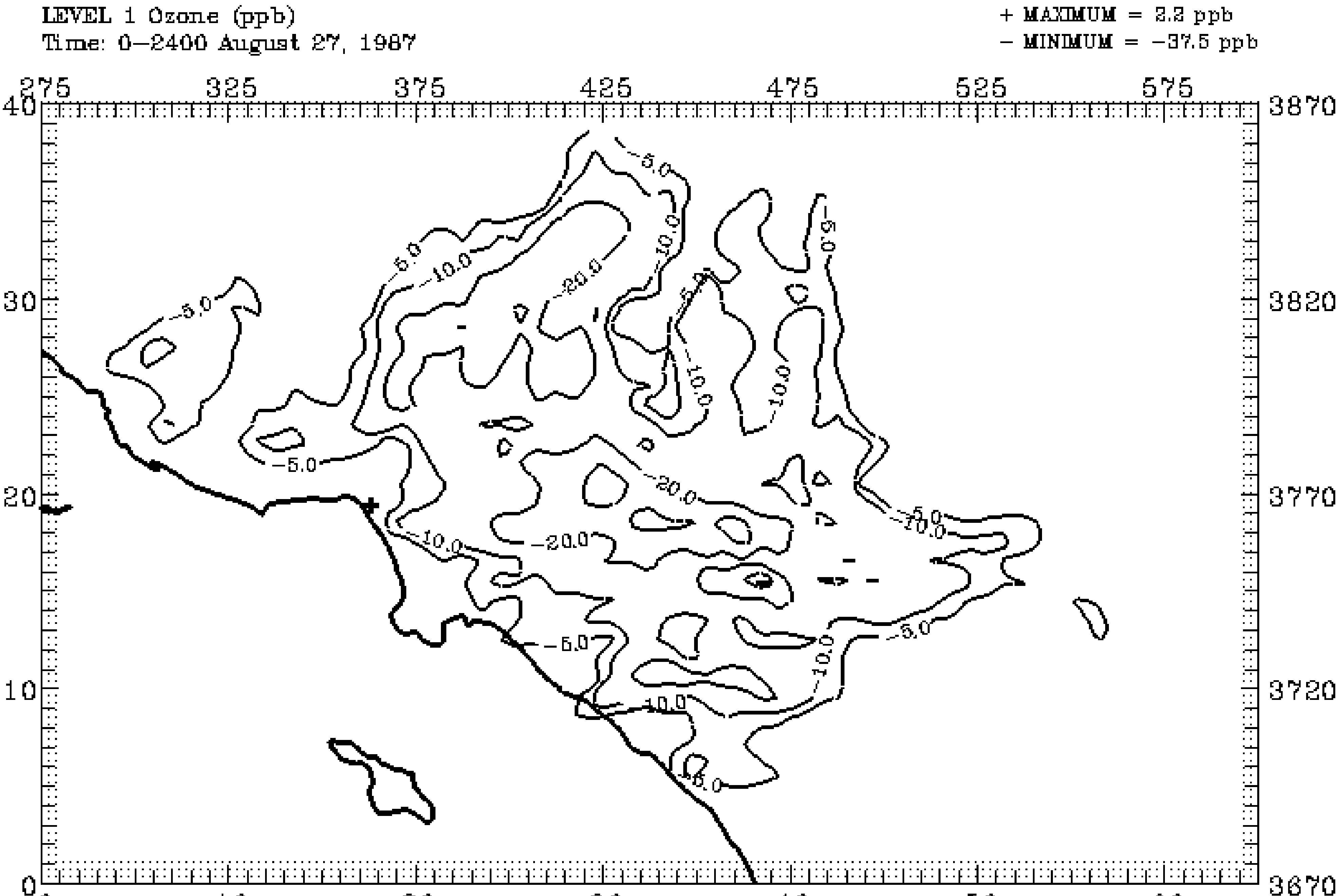


Figure 32b. Difference in maximum simulated ozone concentrations between VOC control run and base year run with standard CB4 - August 27, 1987.

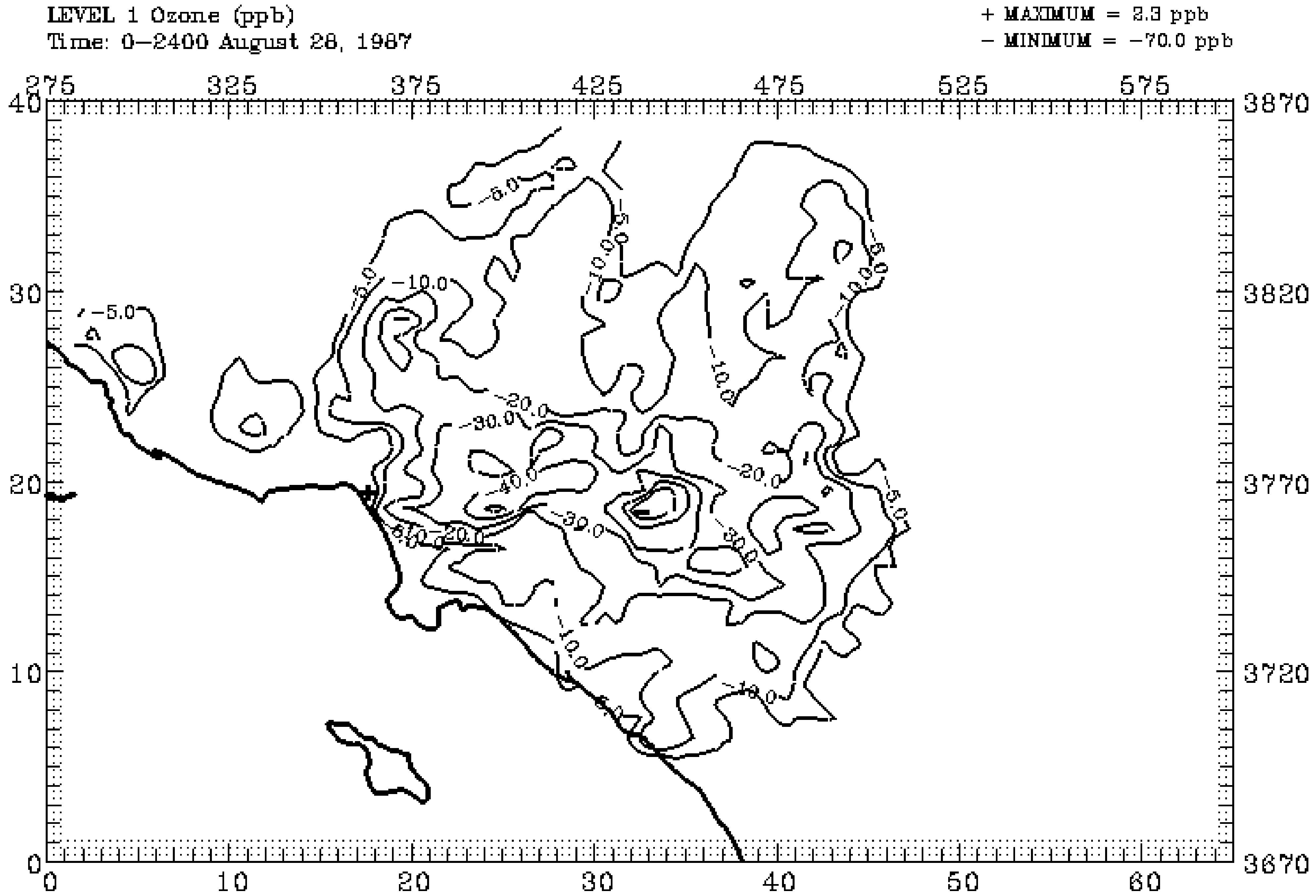


Figure 32c. Difference in maximum simulated ozone concentrations between VOC control run and base year run with standard CB4 - August 28, 1987.

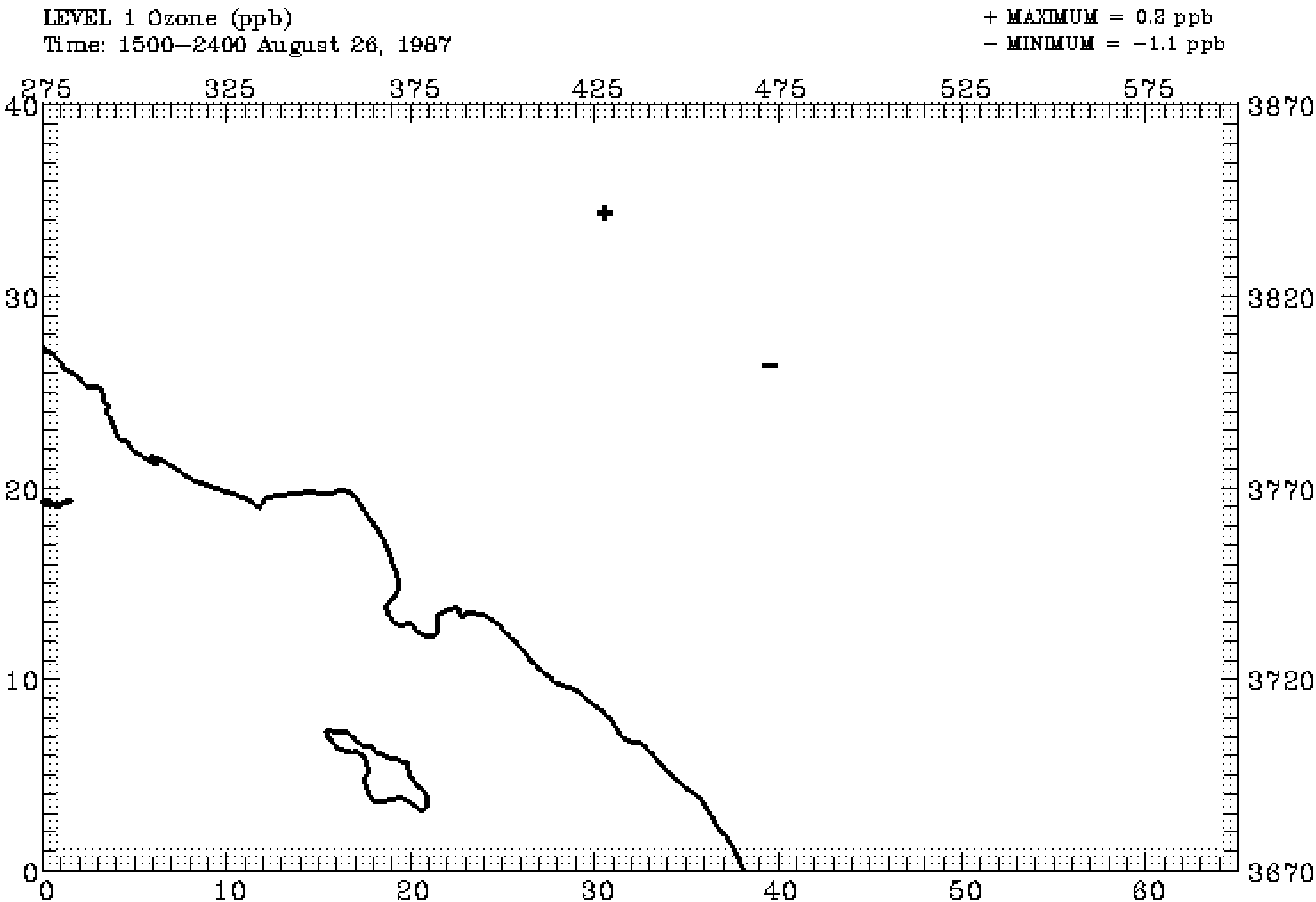


Figure 33a. Difference in maximum simulated ozone concentrations between VOC control run adn base year run with highflux CB4 - August 26, 1987.

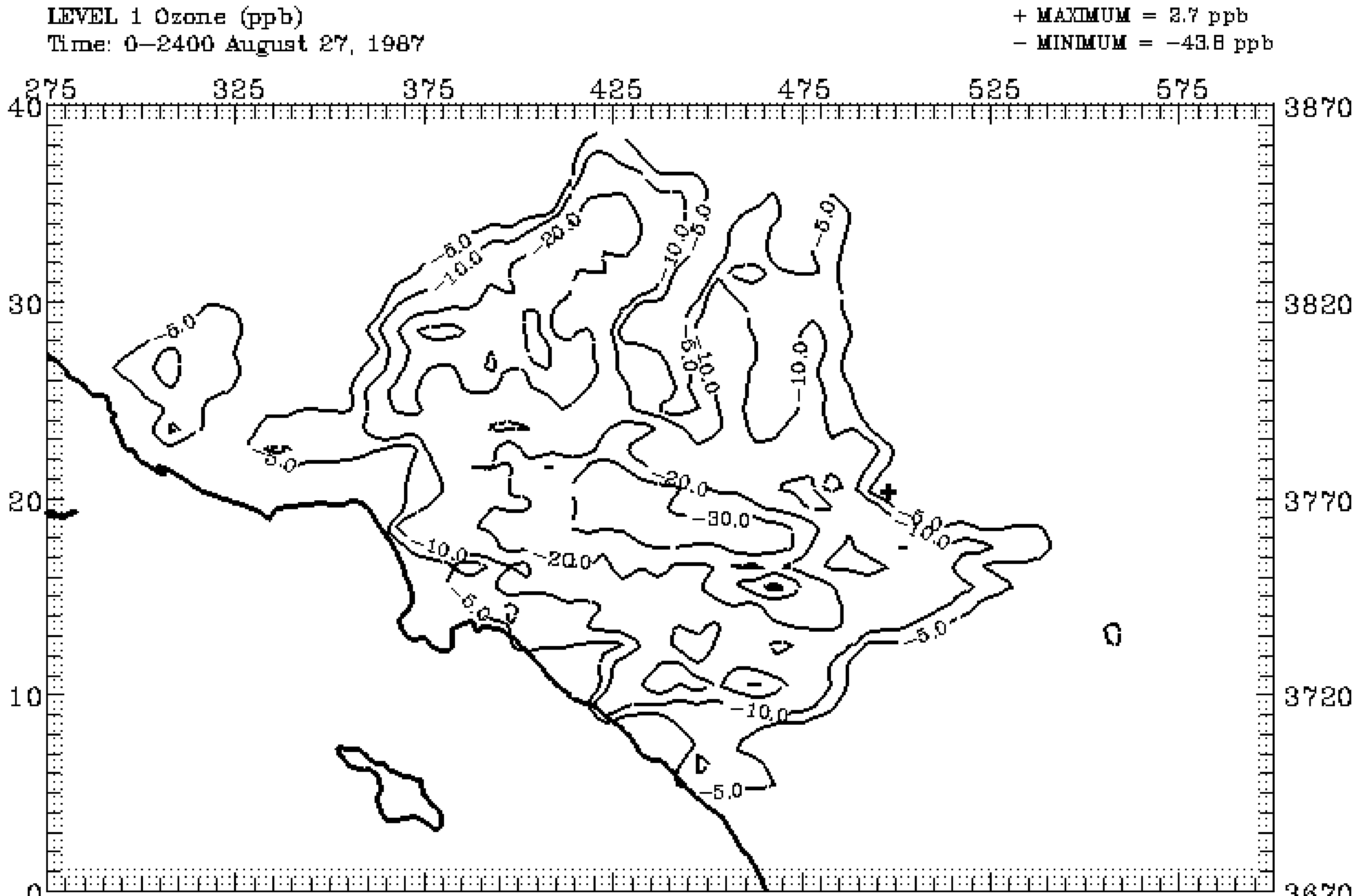


Figure 33b. Difference in maximum simulated ozone concentrations between VOC control run and base year run with highflux CB4 - August 27, 1987.

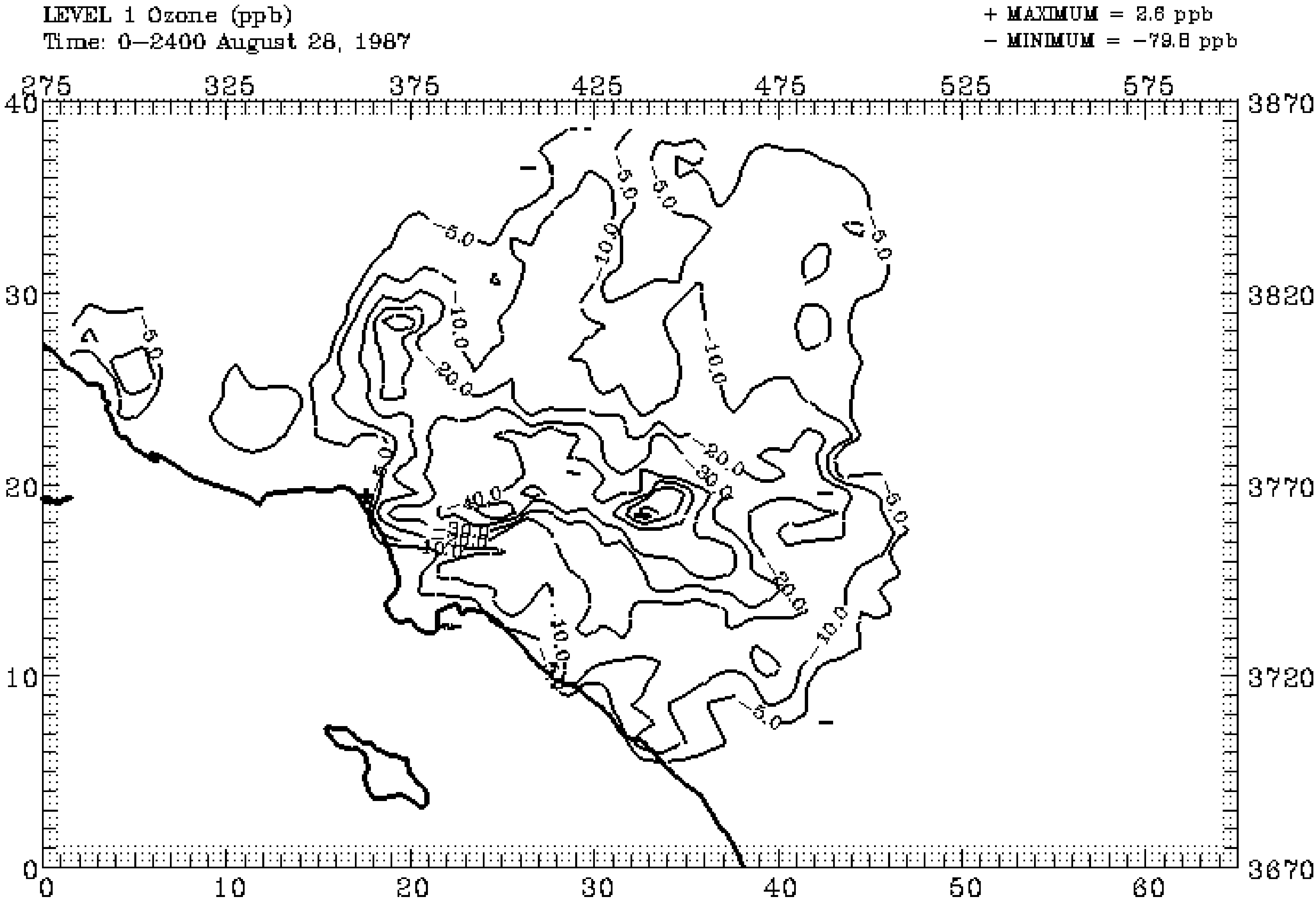


Figure 33c. Difference in maximum simulated ozone concentrations between VOC control run and base year run with highflux CB4 - August 28, 1987.

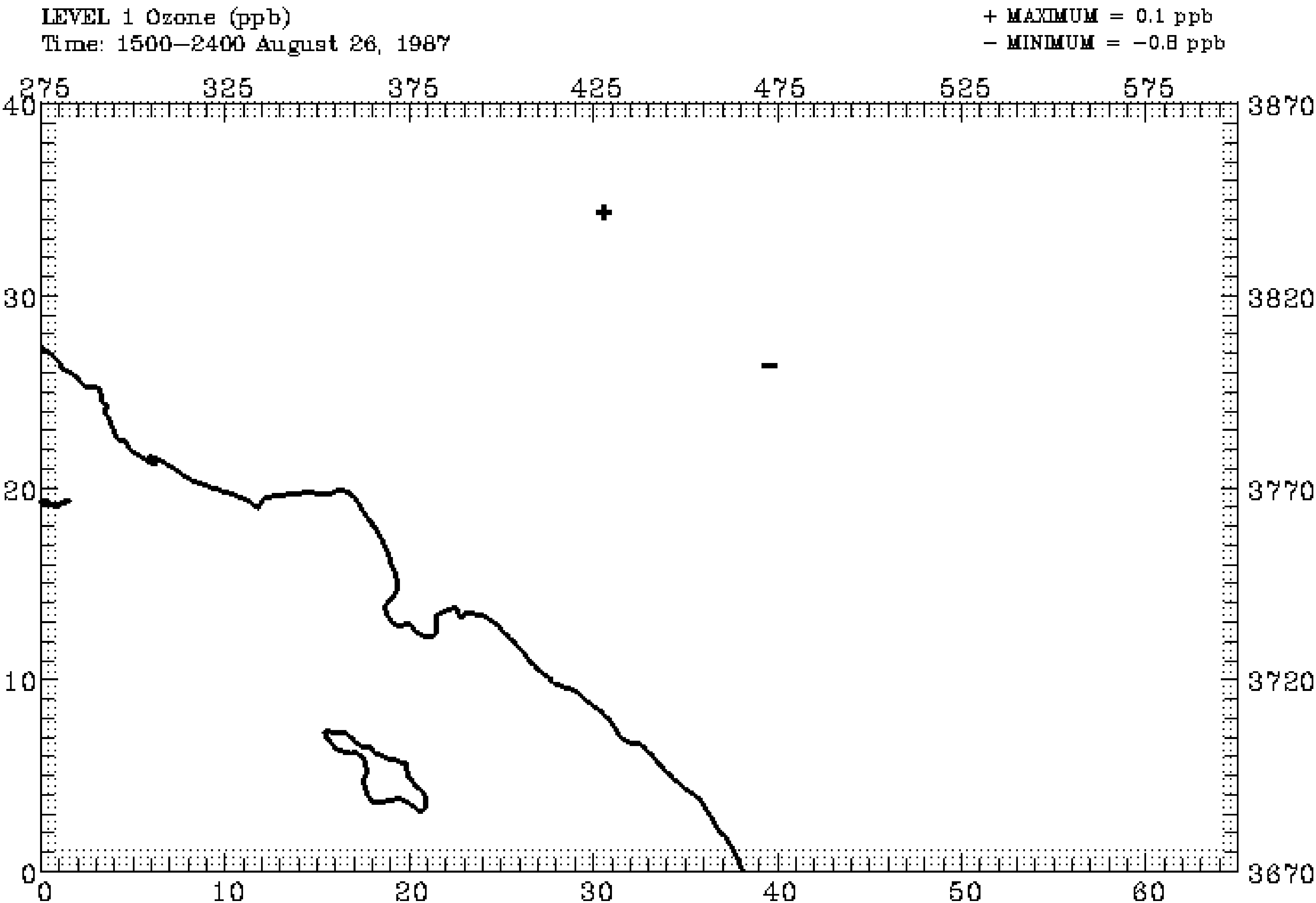


Figure 34a. Difference in maximum simulated ozone concentrations between VOC control run and base year run with lowflux CB4 - August 26, 1987.

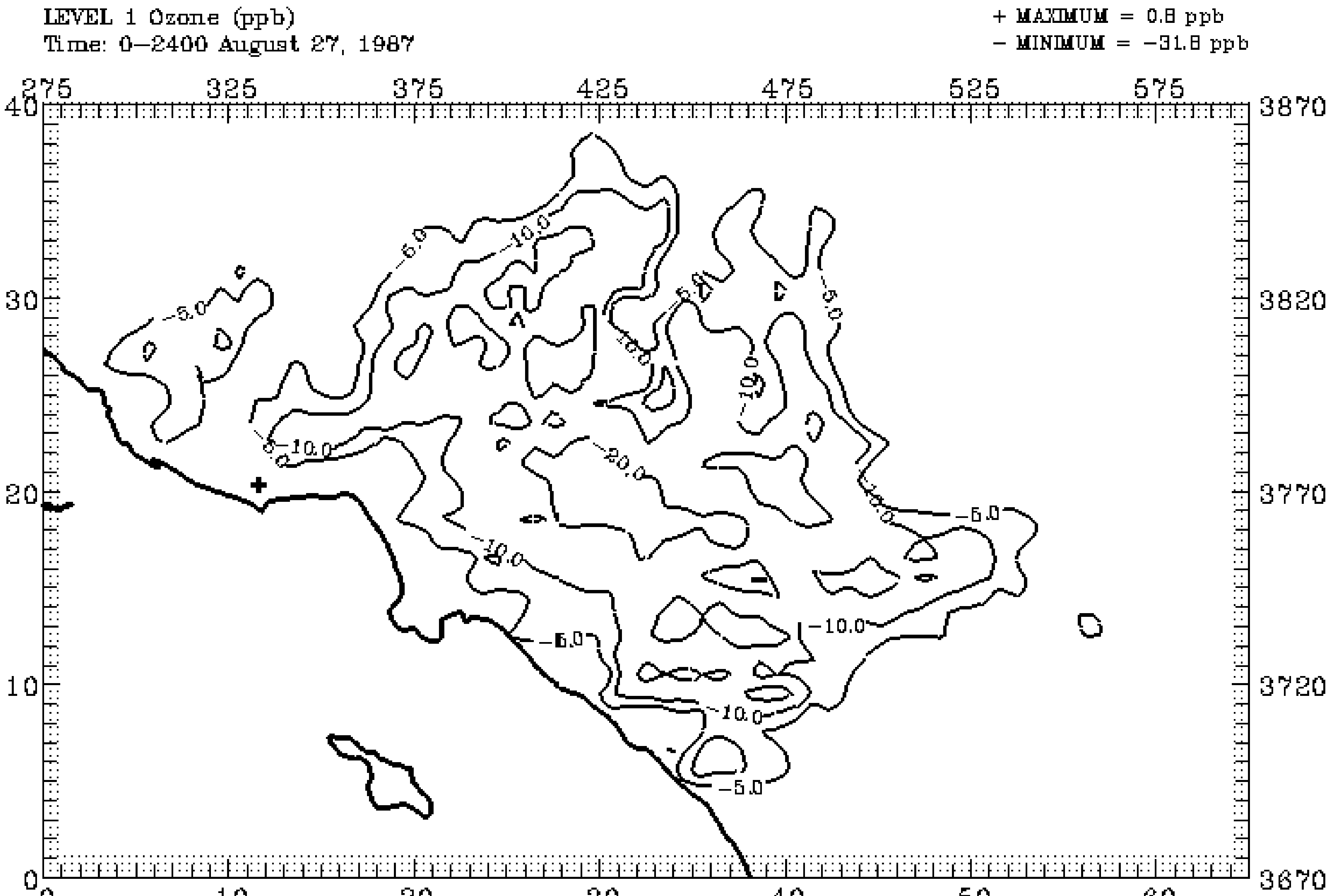


Figure 34b. Difference in maximum simulated ozone concentrations between VOC control run and base year run with lowflux CB4 - August 27, 1987.

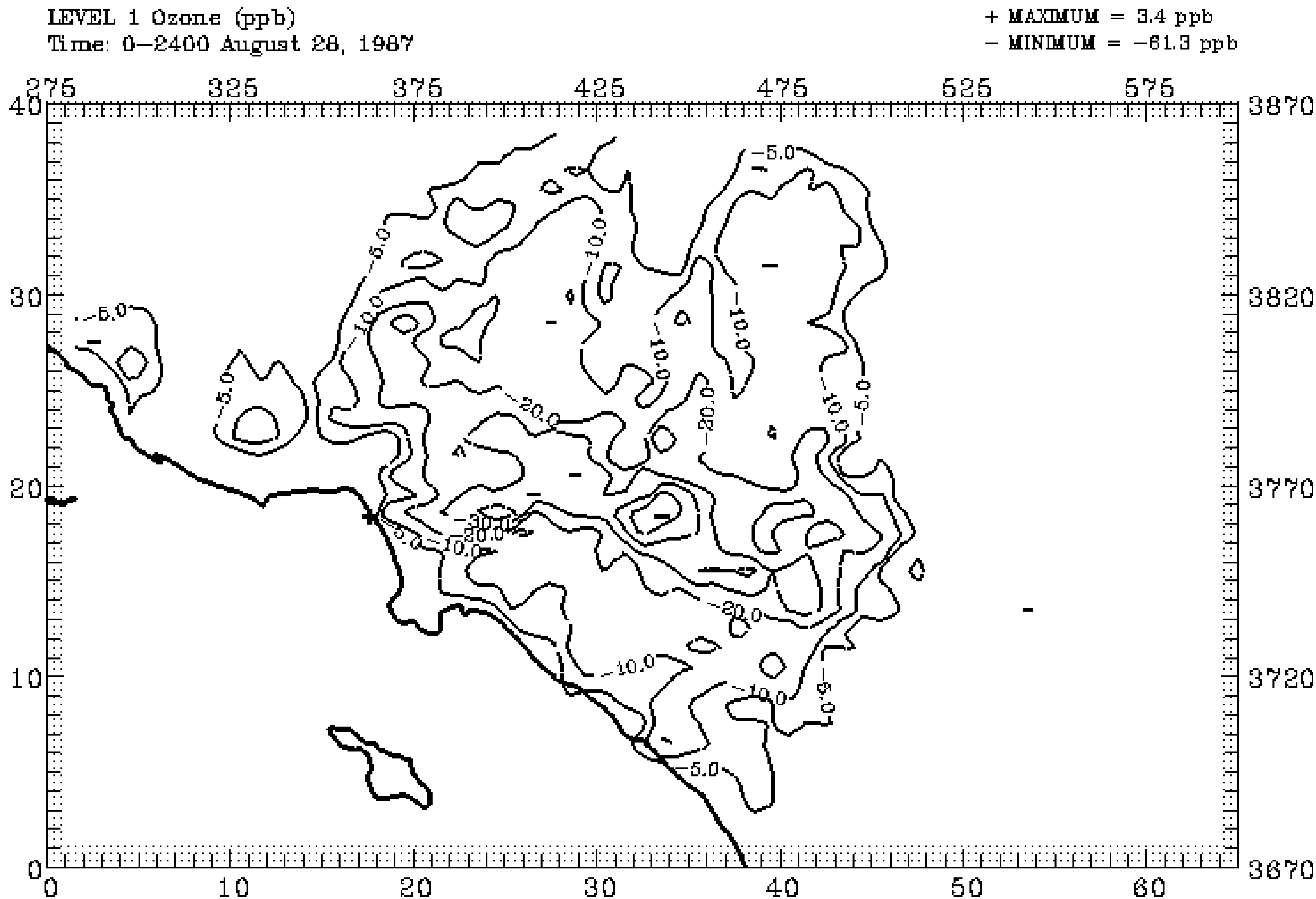


Figure 34c. Difference in maximum simulated ozone concentrations between VOC control run and base year run with lowflux CB4 - August 28, 1987.

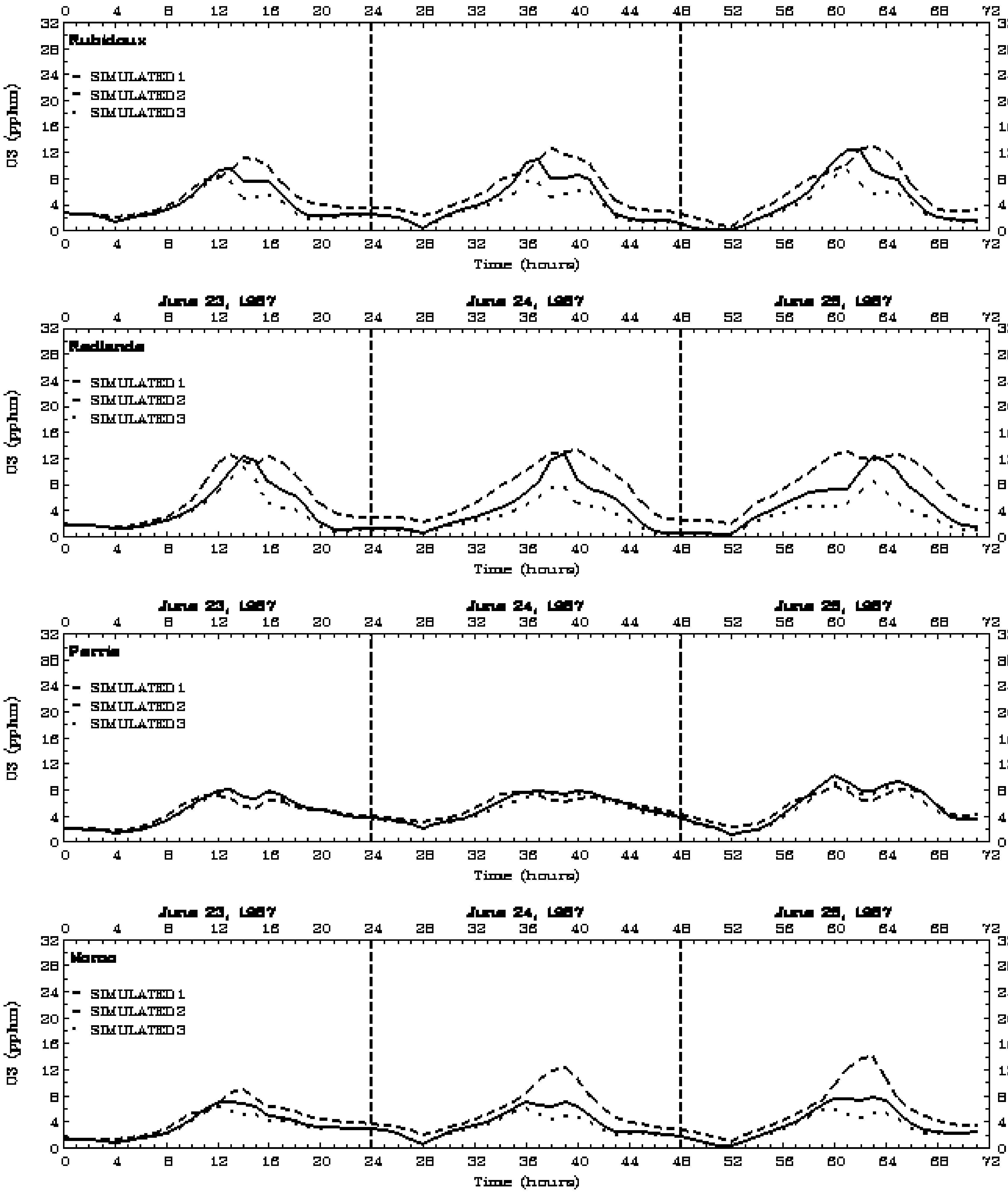


Figure 35. Time Series of simulated ozone concentrations with standard CB4 for 1987 June Episode.

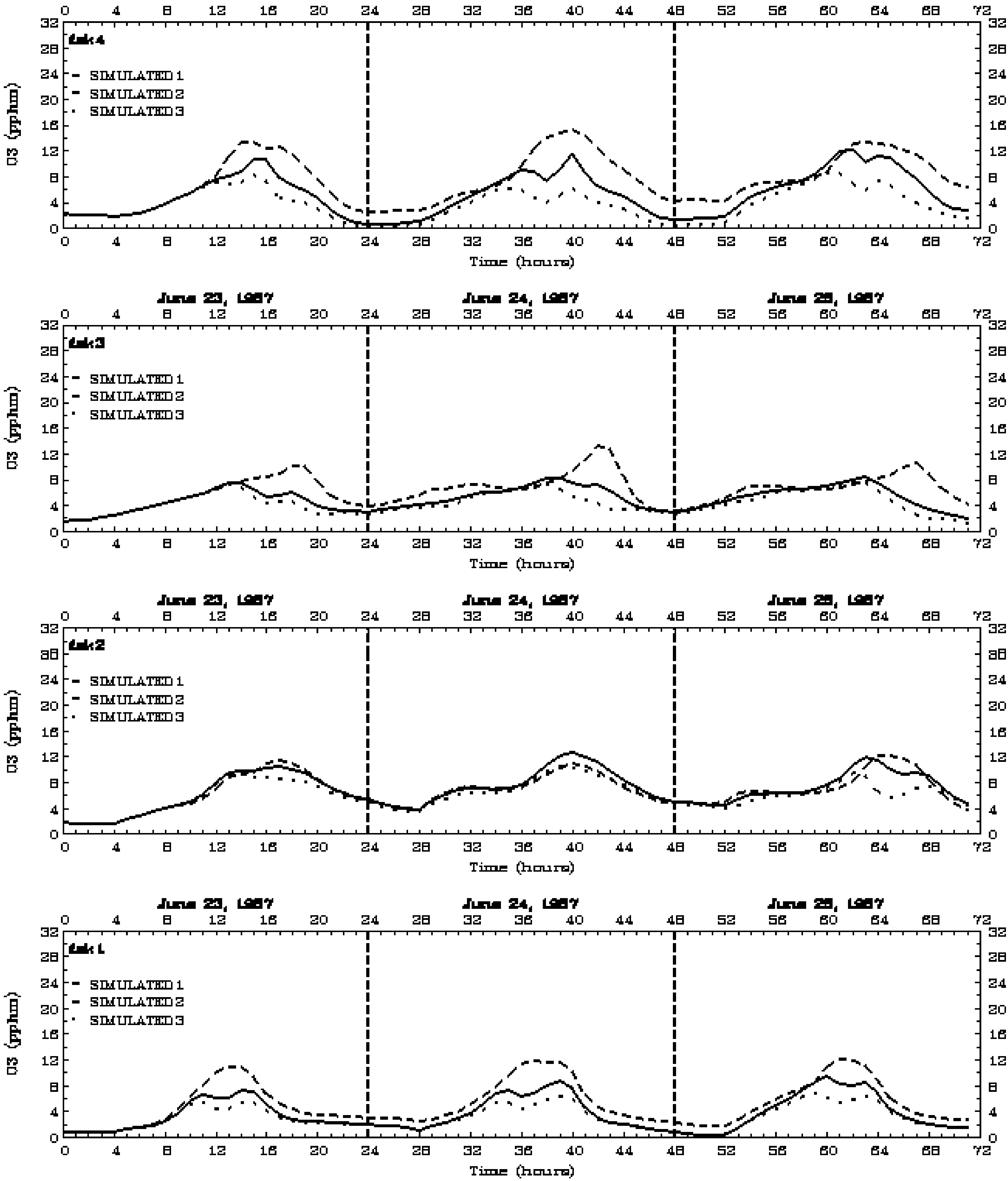
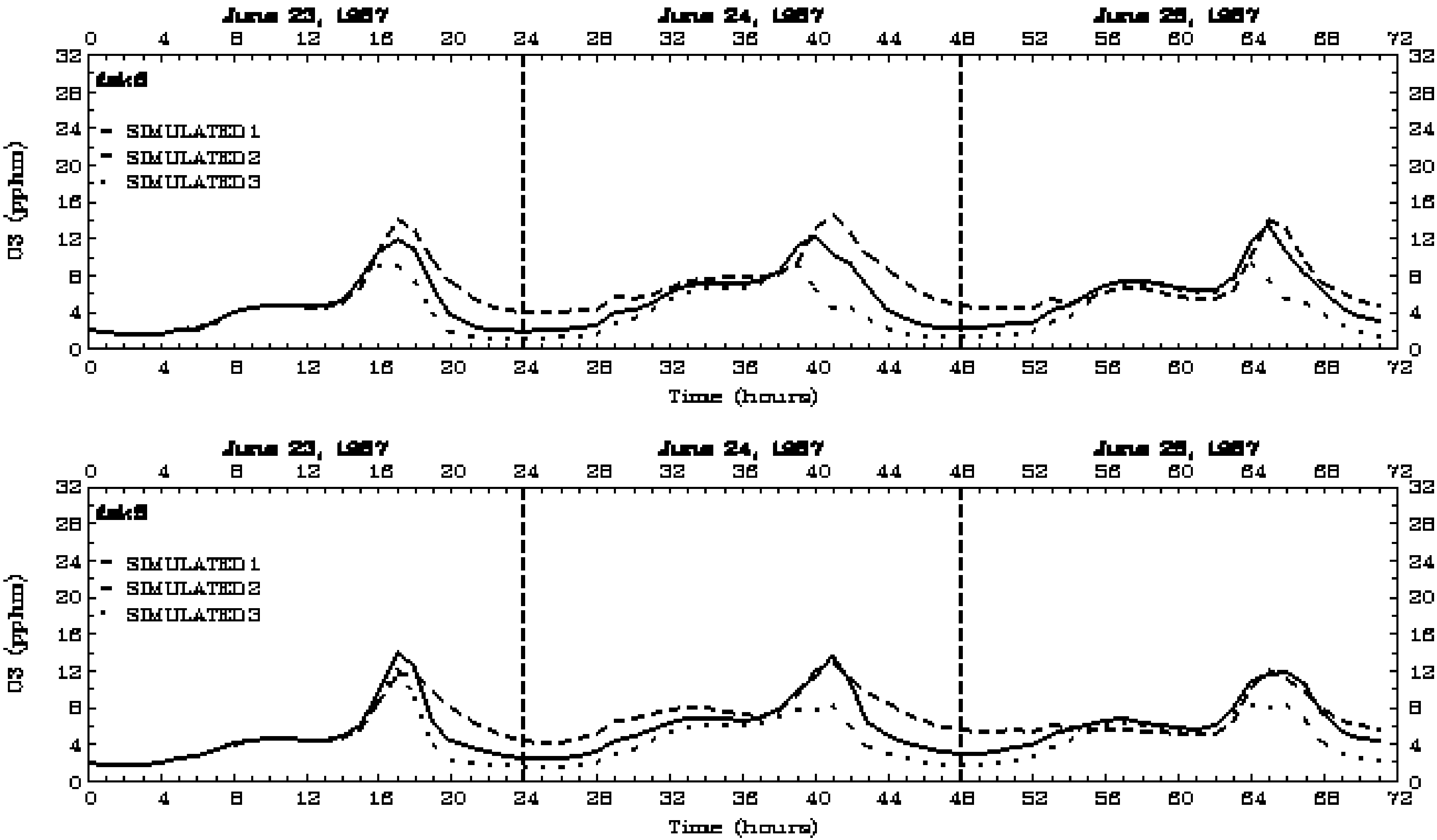


Figure 35. Continued.



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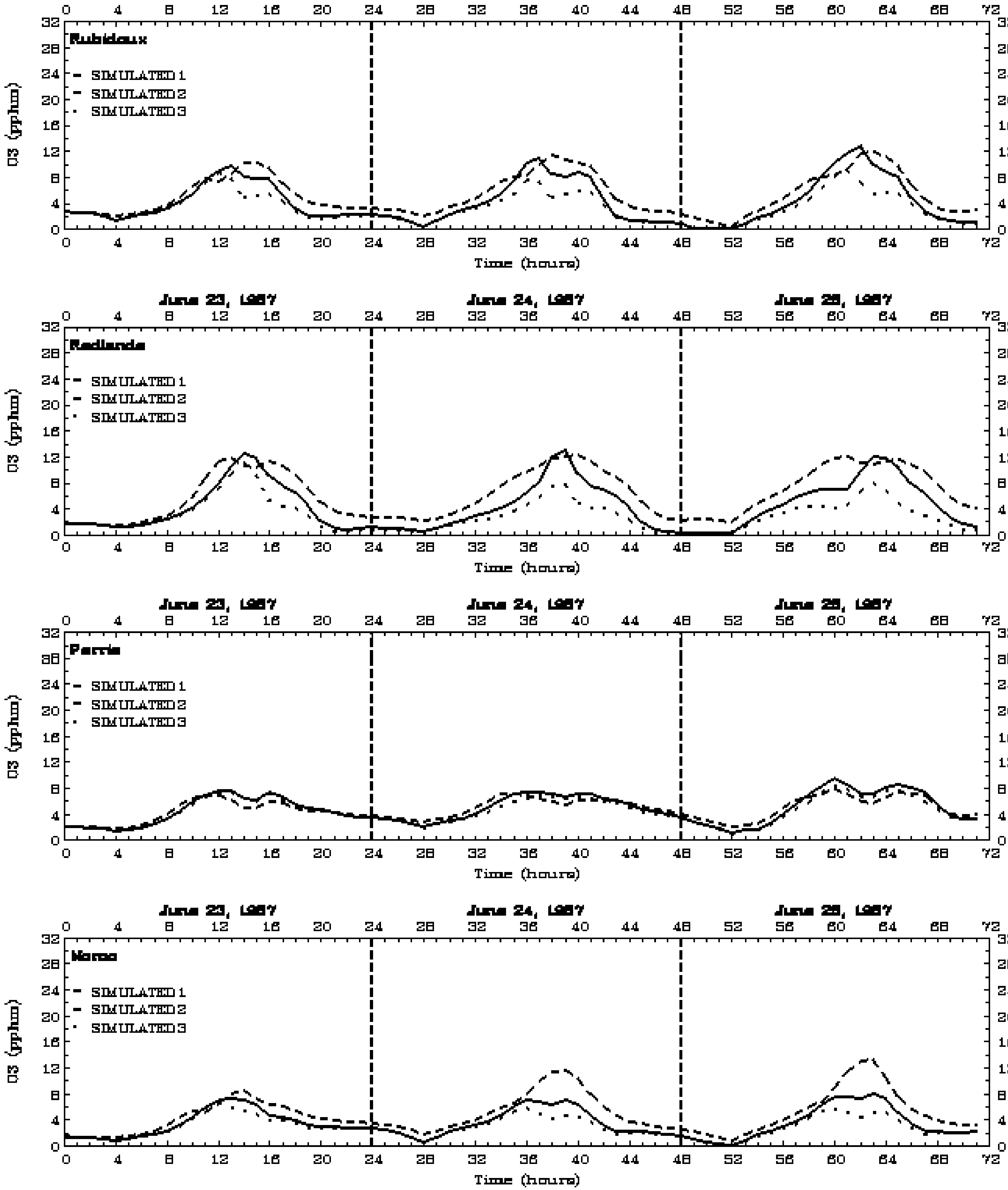


Figure 36. Time Series of simulated ozone concentrations with highflux CB4 for 1987 June Episode.

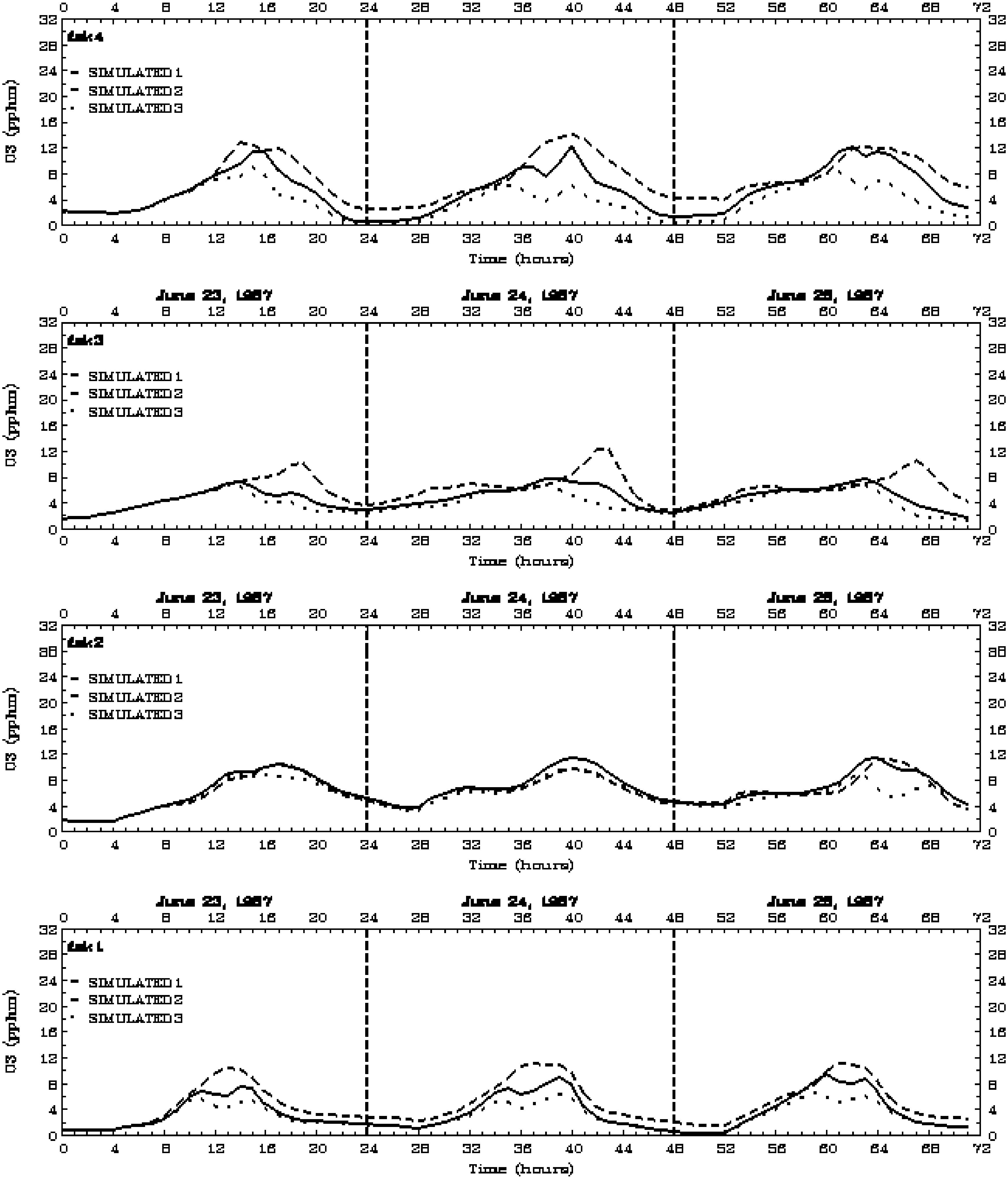


Figure 36. Continued.

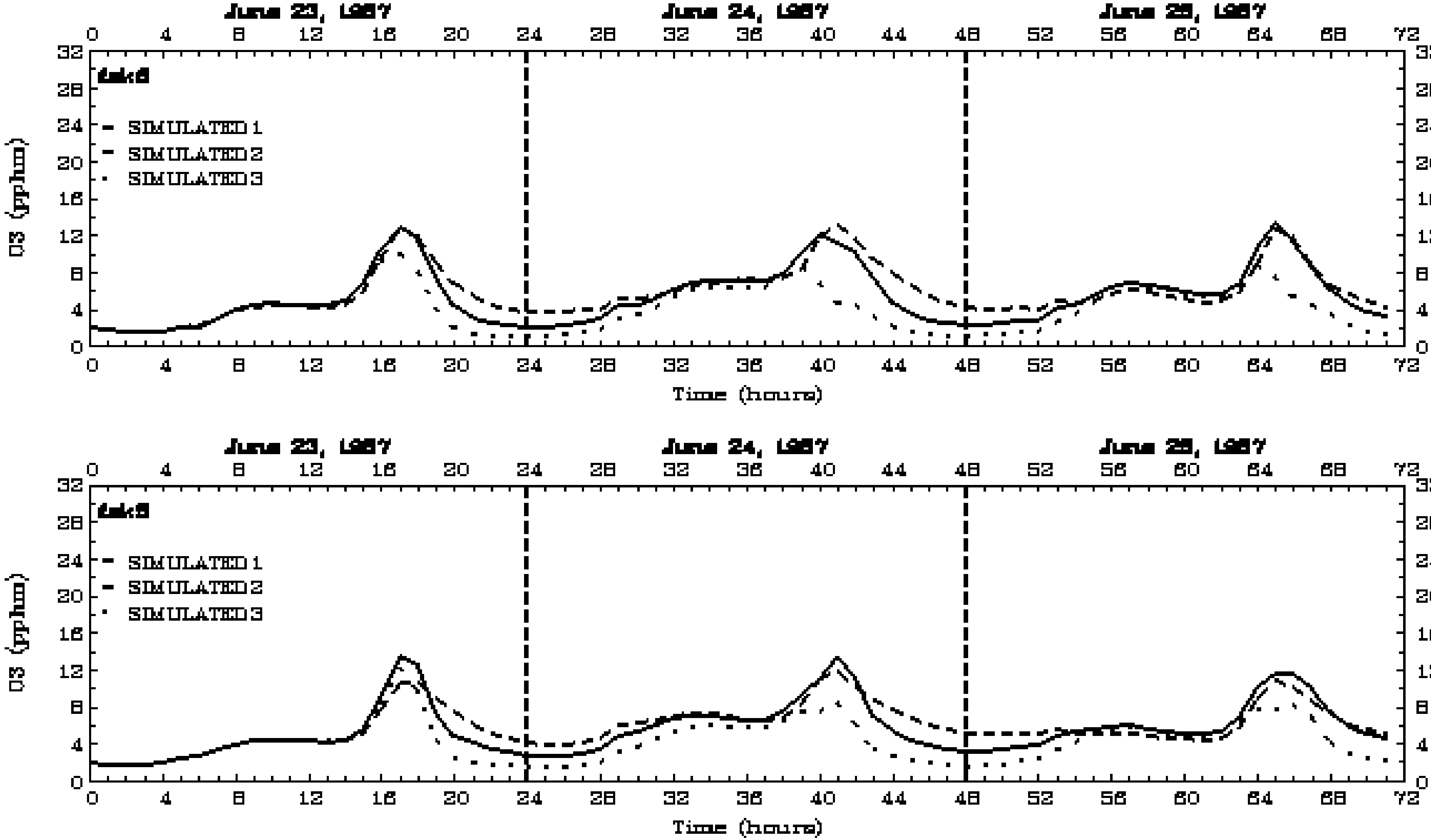


Figure 36. Continued.

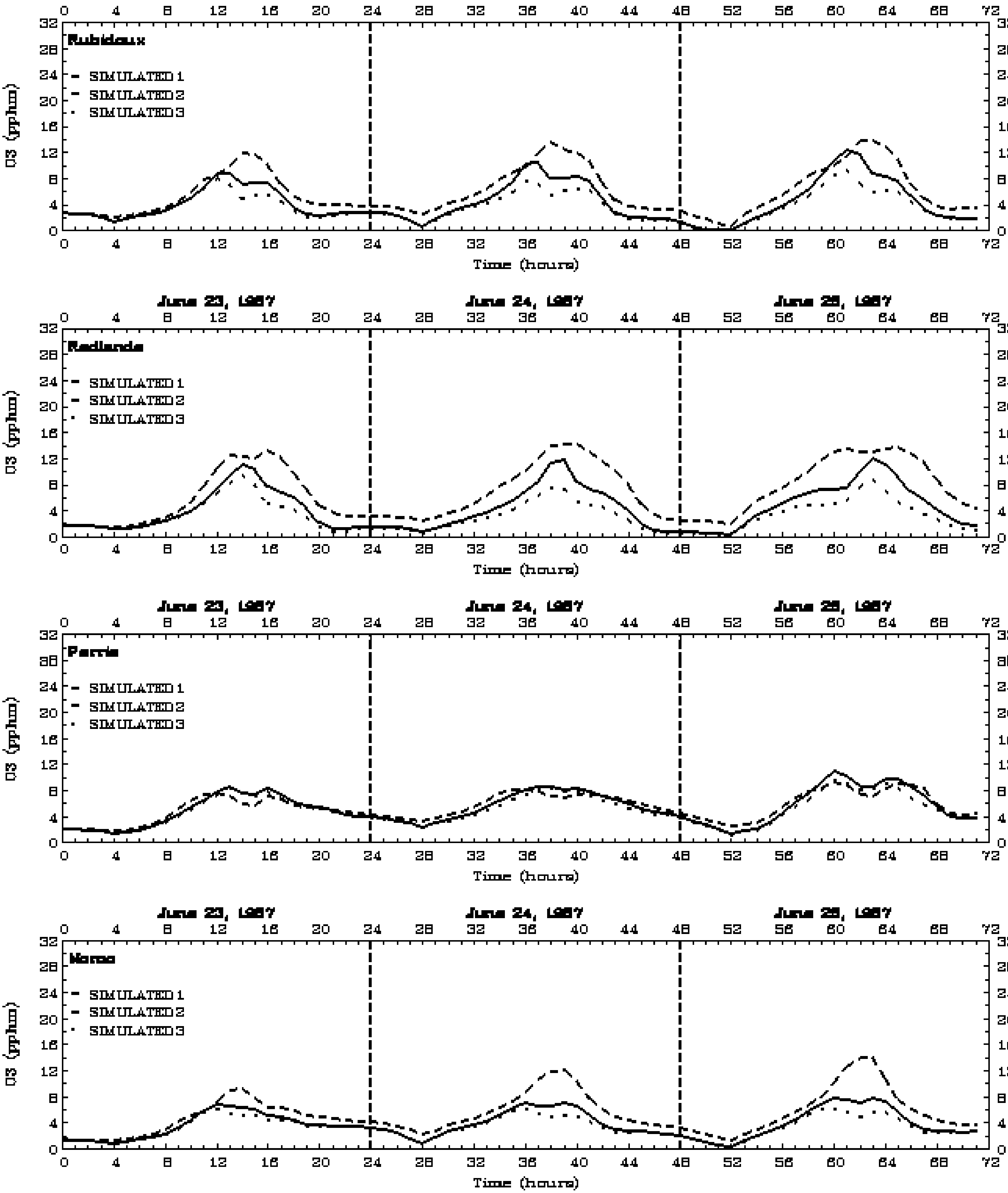


Figure 37. Time Series of simulated ozone concentrations with lowflux CB4 for 1987 June Episode.

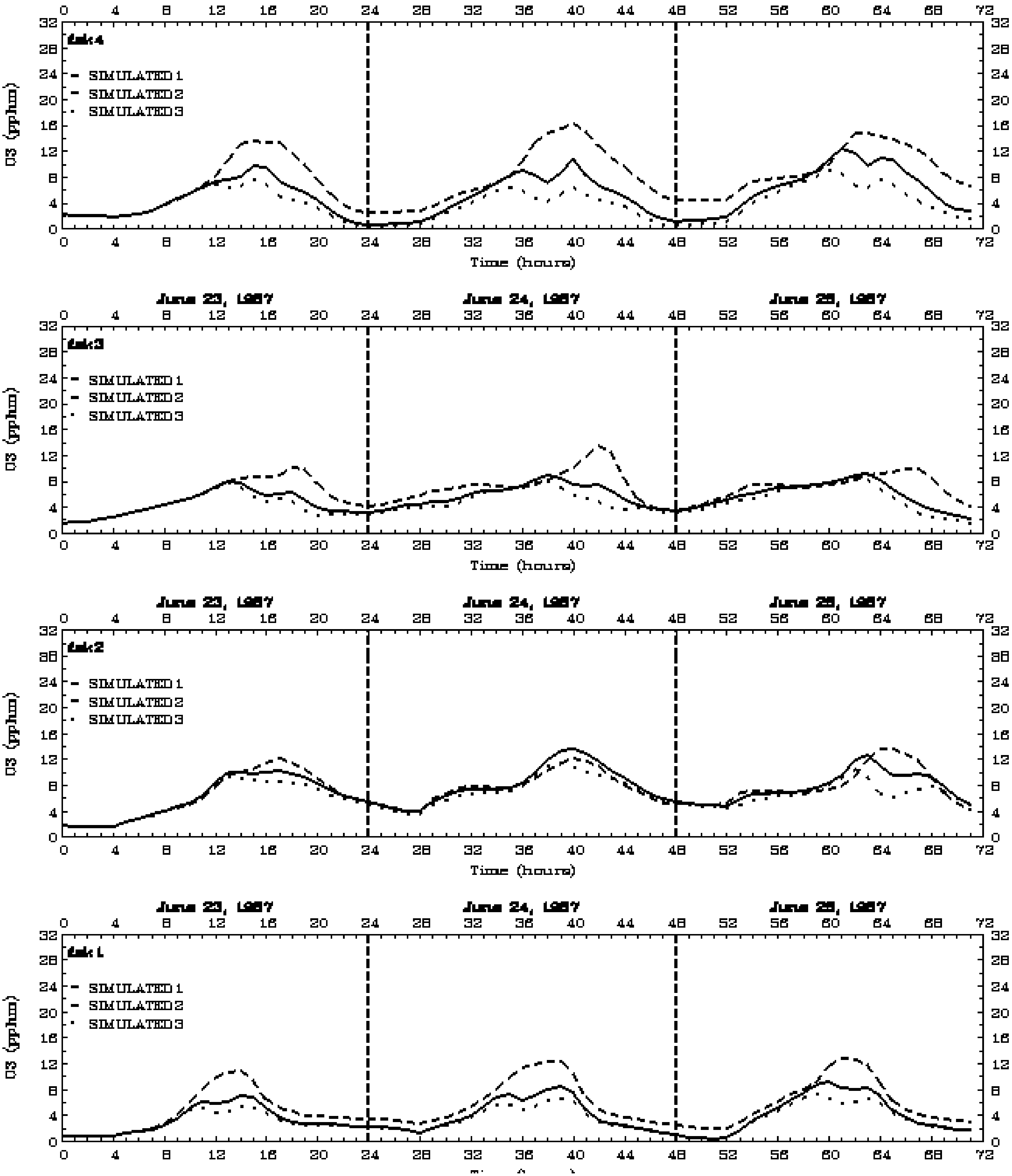


Figure 37. Continued.

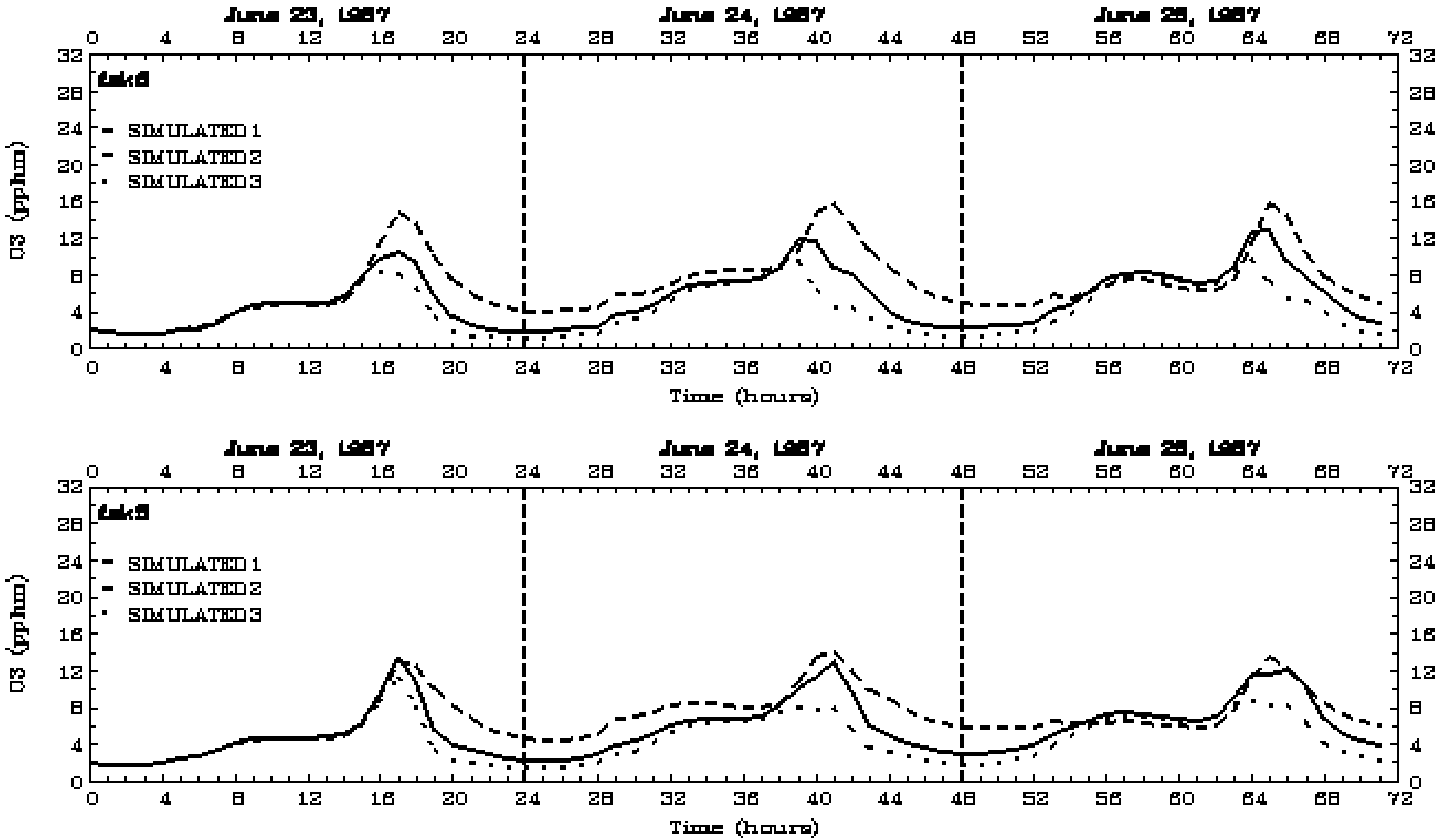


Figure 37. Continued.

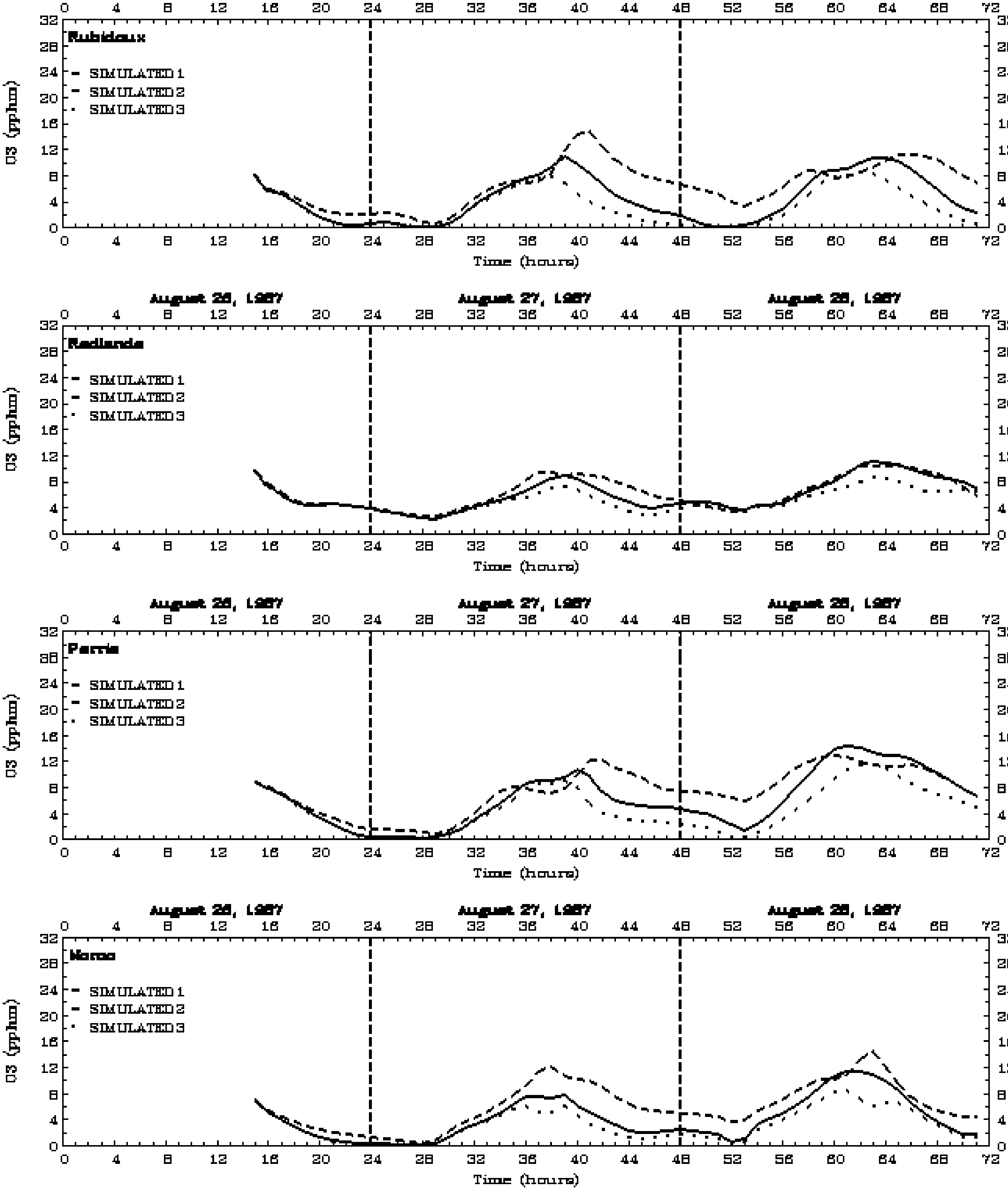


Figure 38. Time Series of simulated ozone concentrations with standard CB4 for 1987 August Episode.

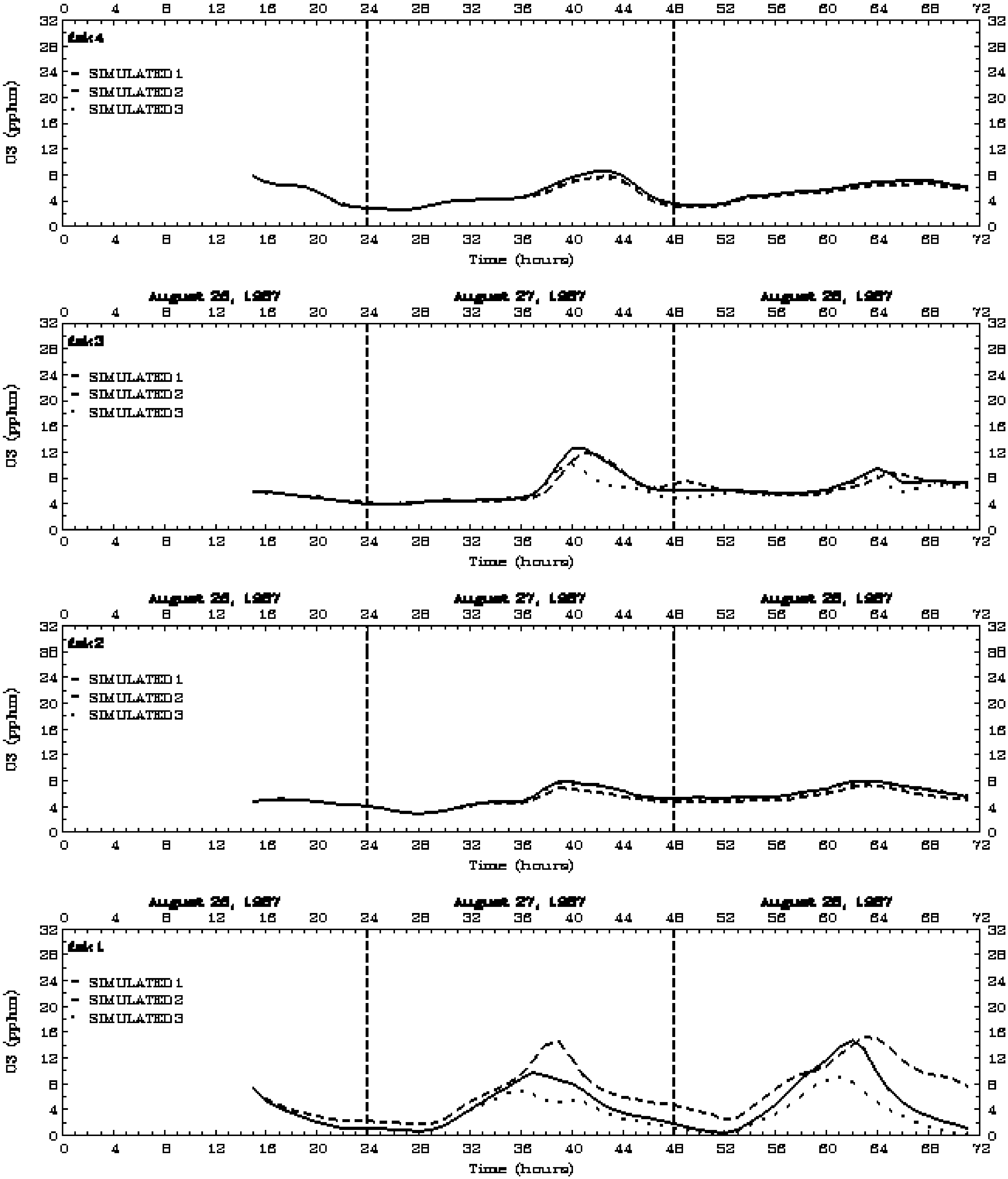


Figure 38. Continued.

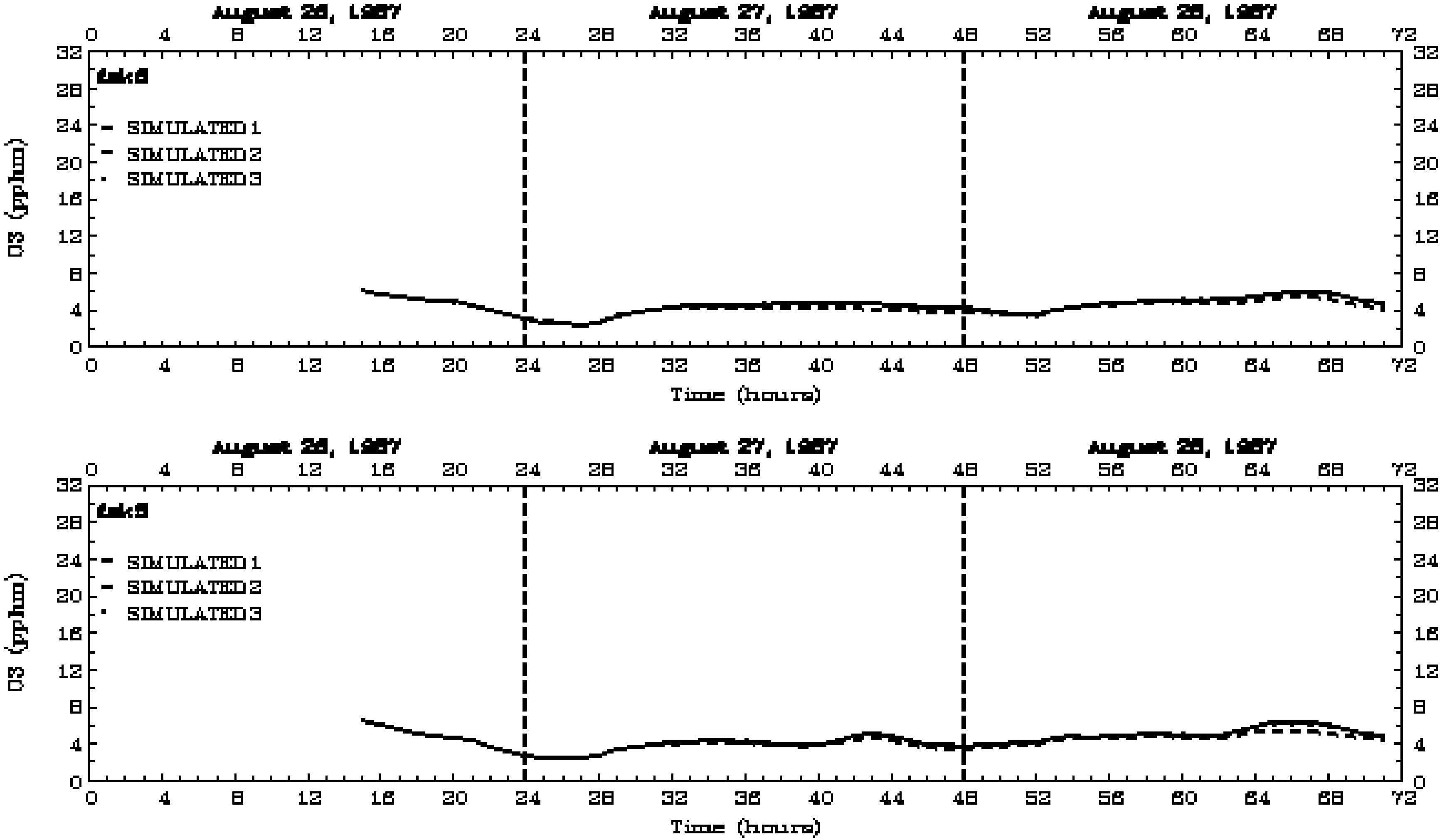


Figure 38. Continued.

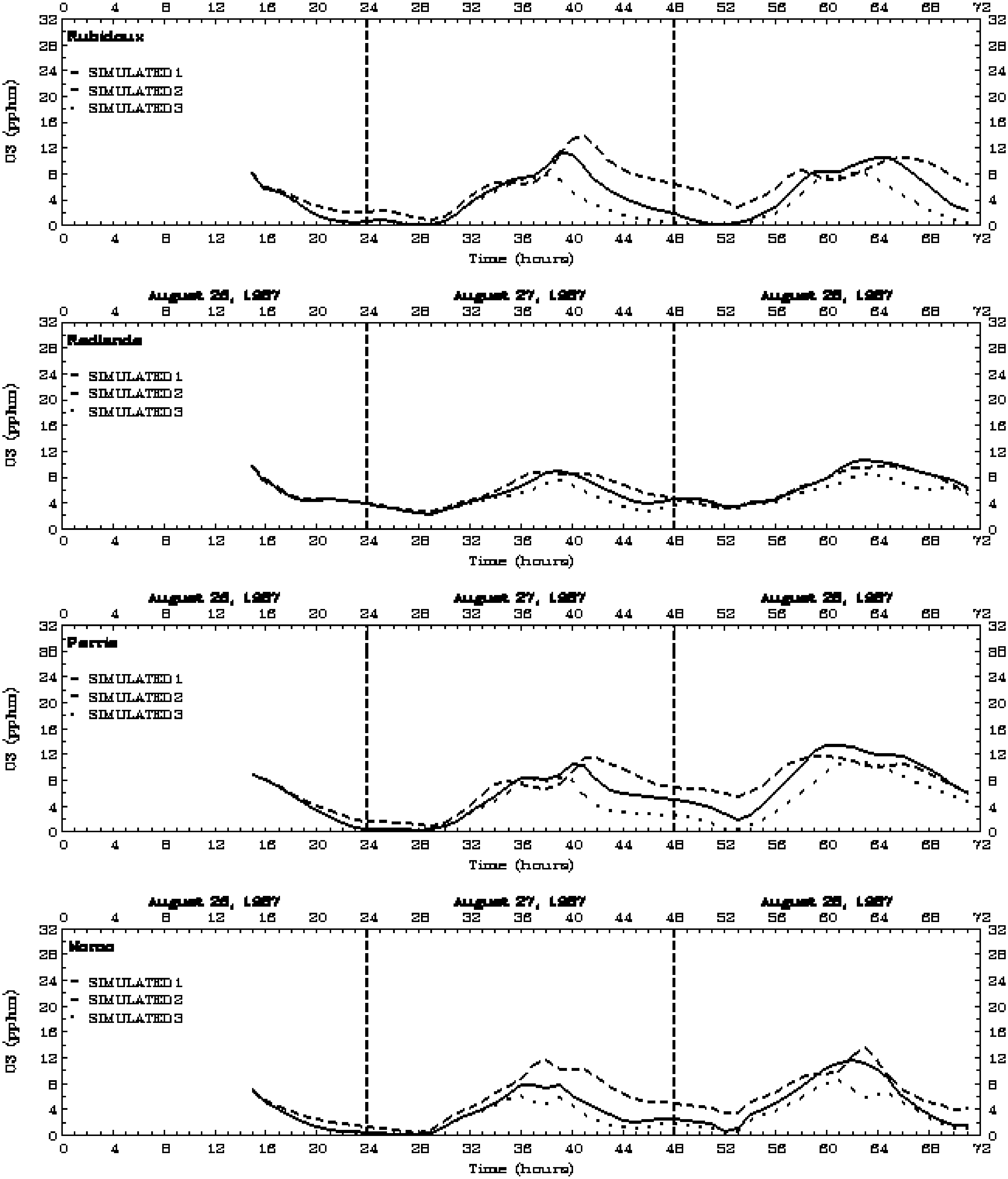


Figure 39. Time Series of simulated ozone concentrations with highflux CB4 for 1987 August Episode.

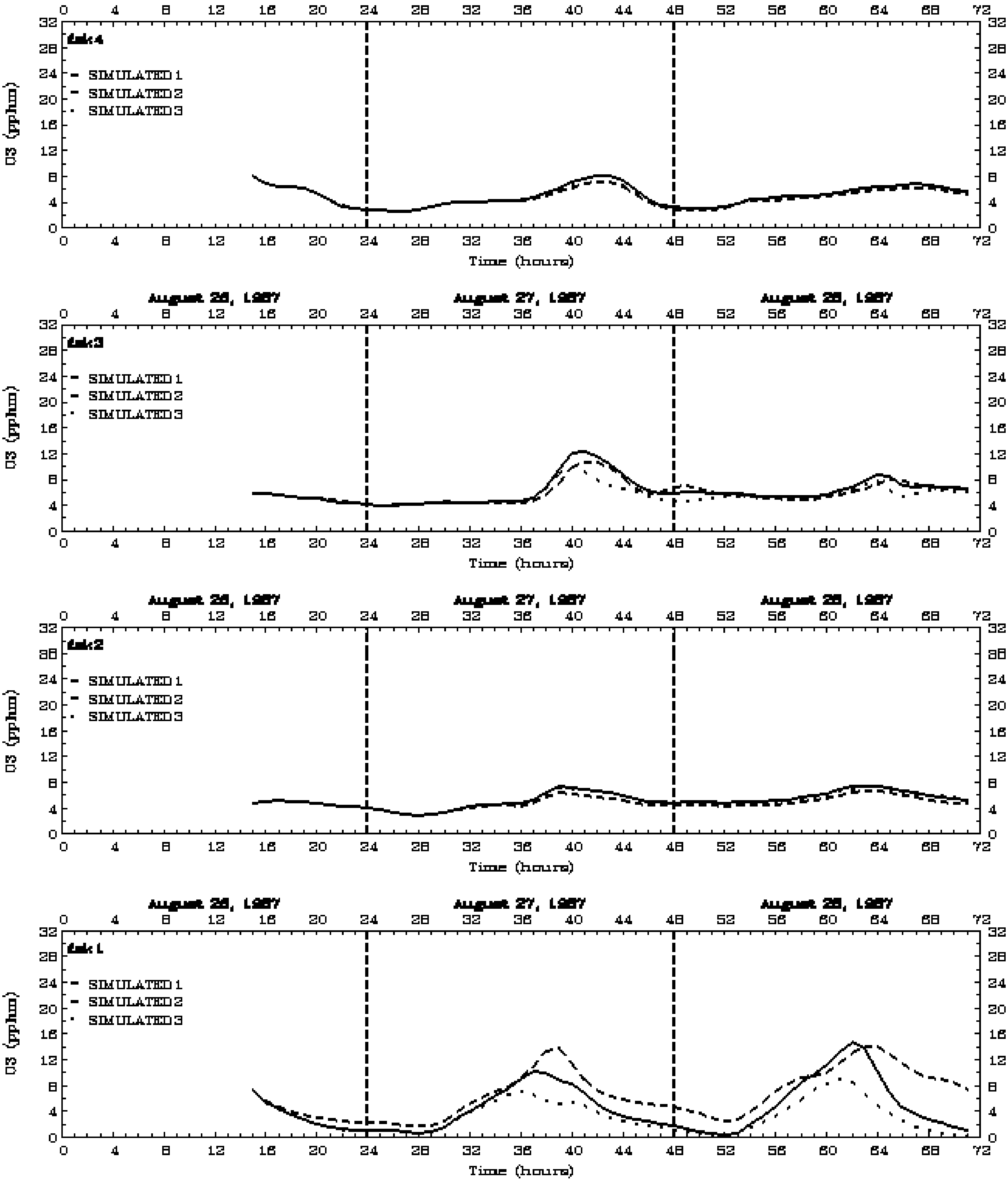


Figure 39. Continued.

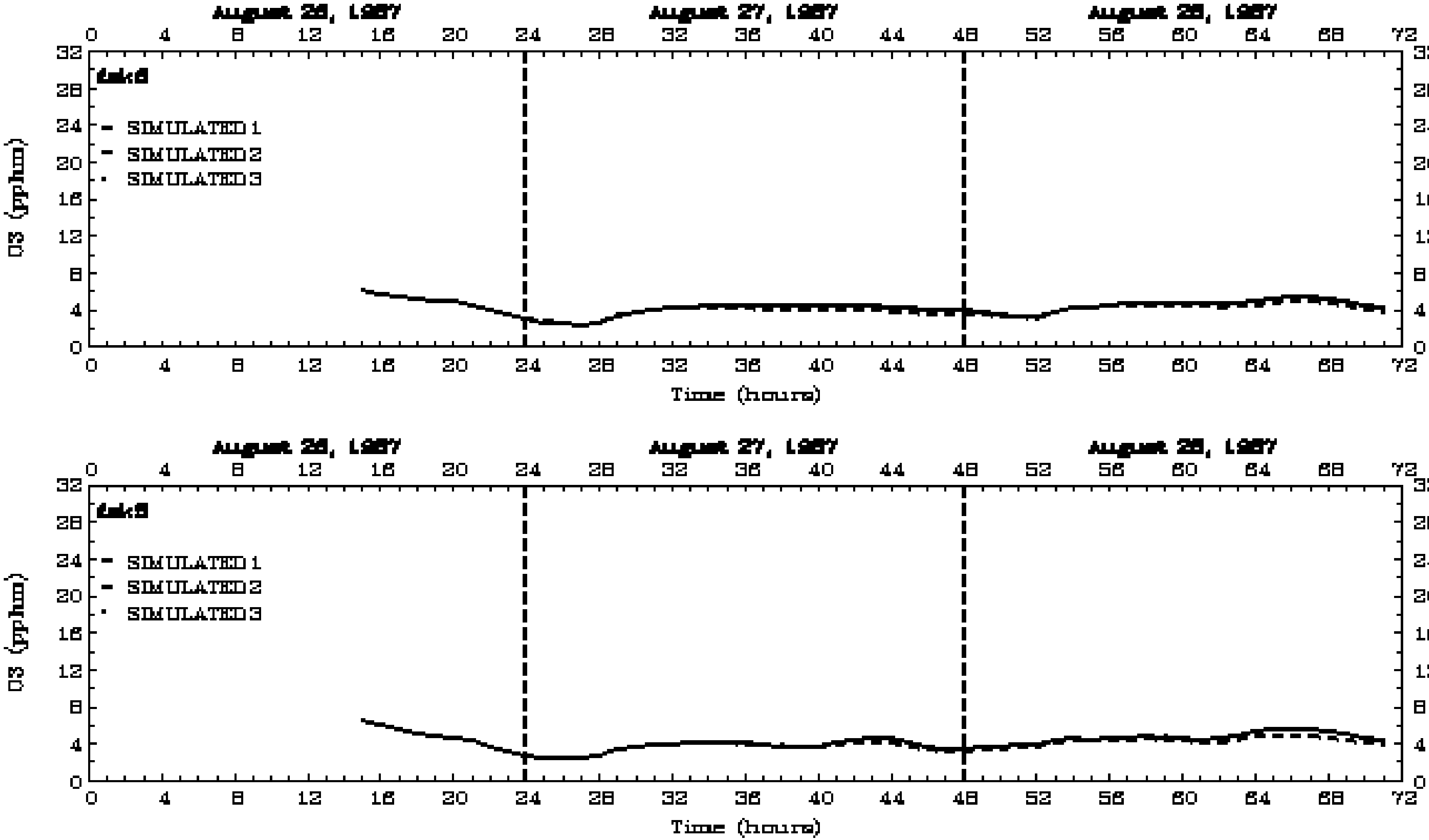


Figure 39. Continued.

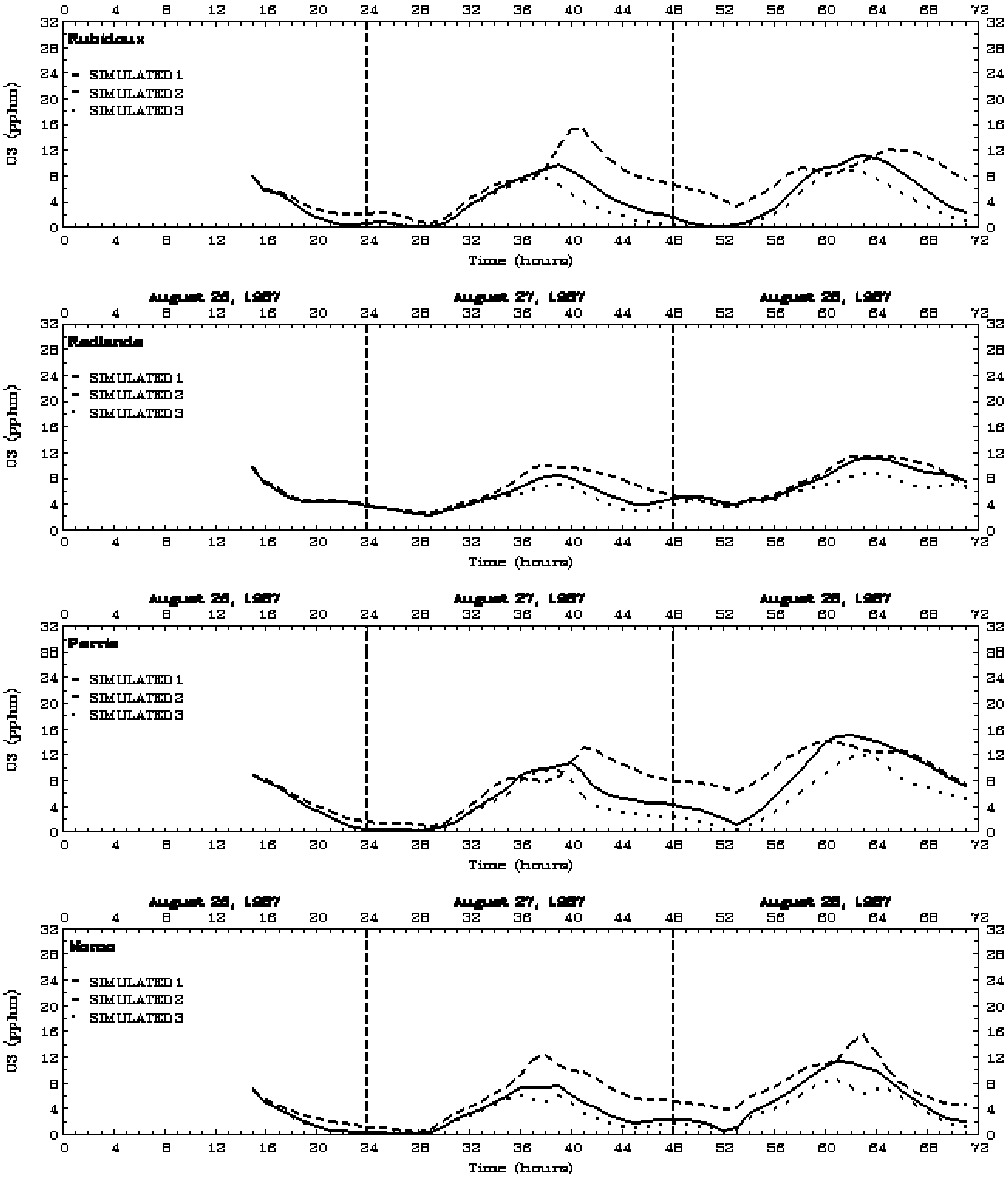


Figure 40. Time Series of simulated ozone concentrations with lowflux CB4 for 1987 August Episode.

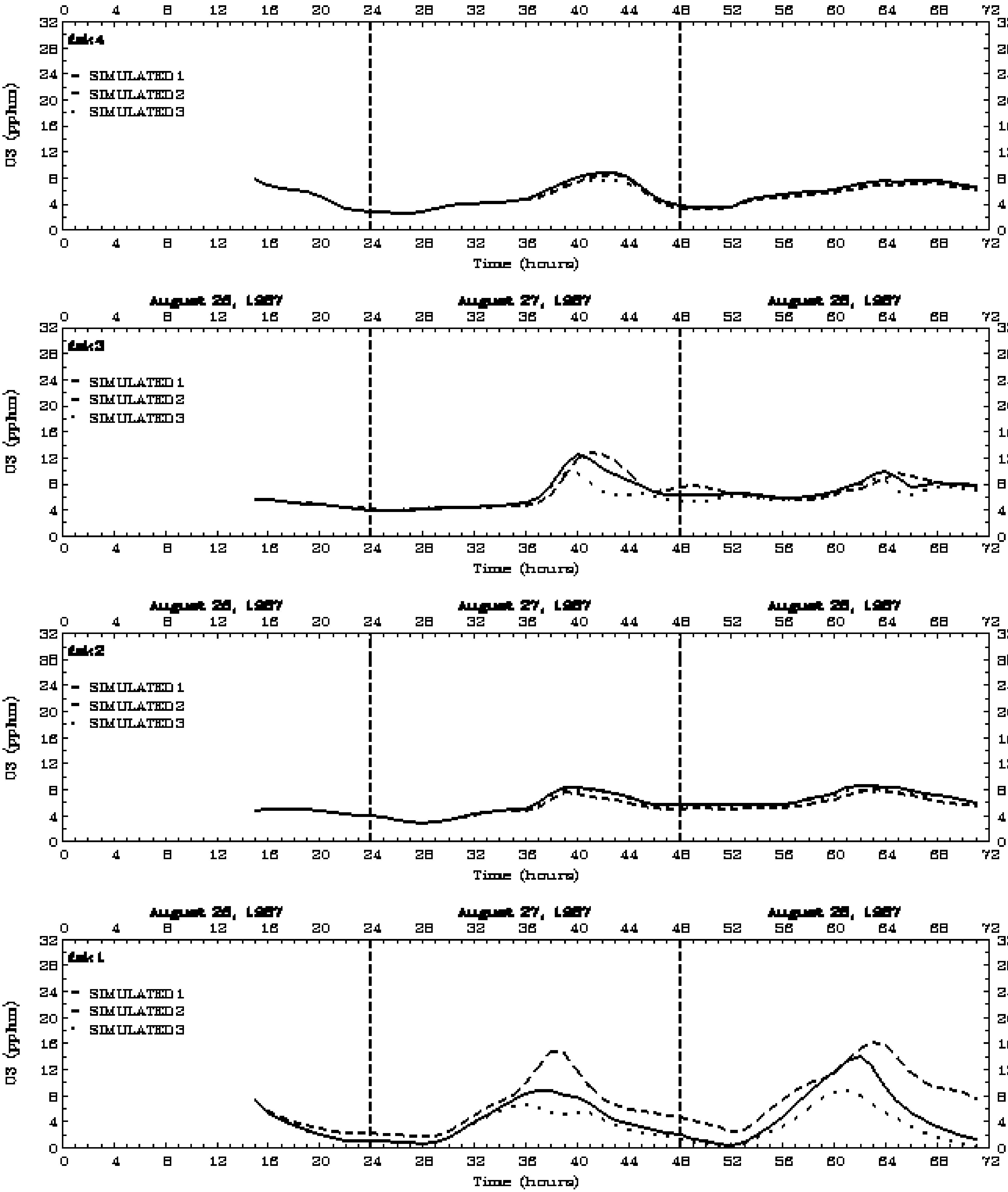


Figure 40. Continued.

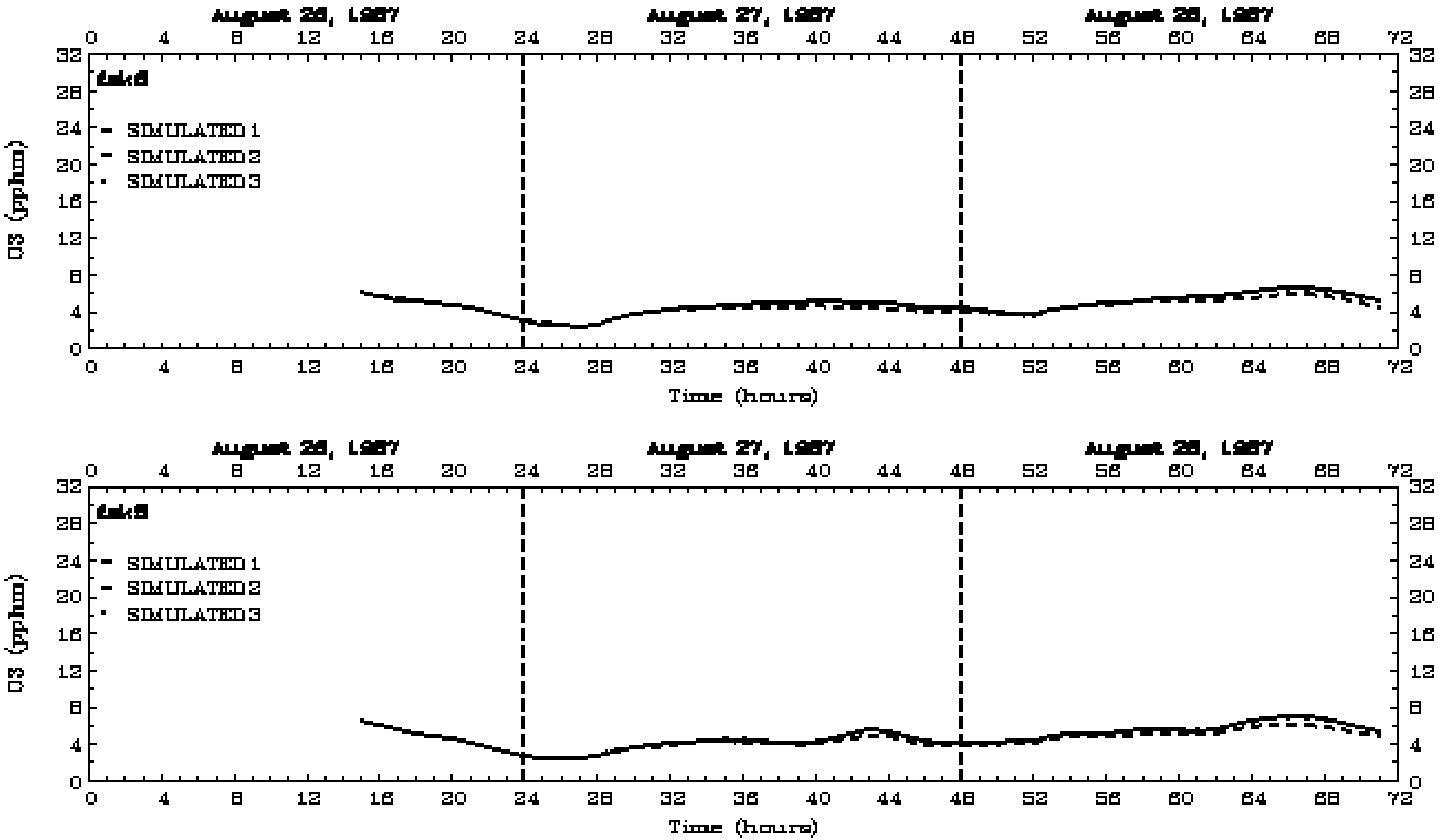


Figure 40. Continued.

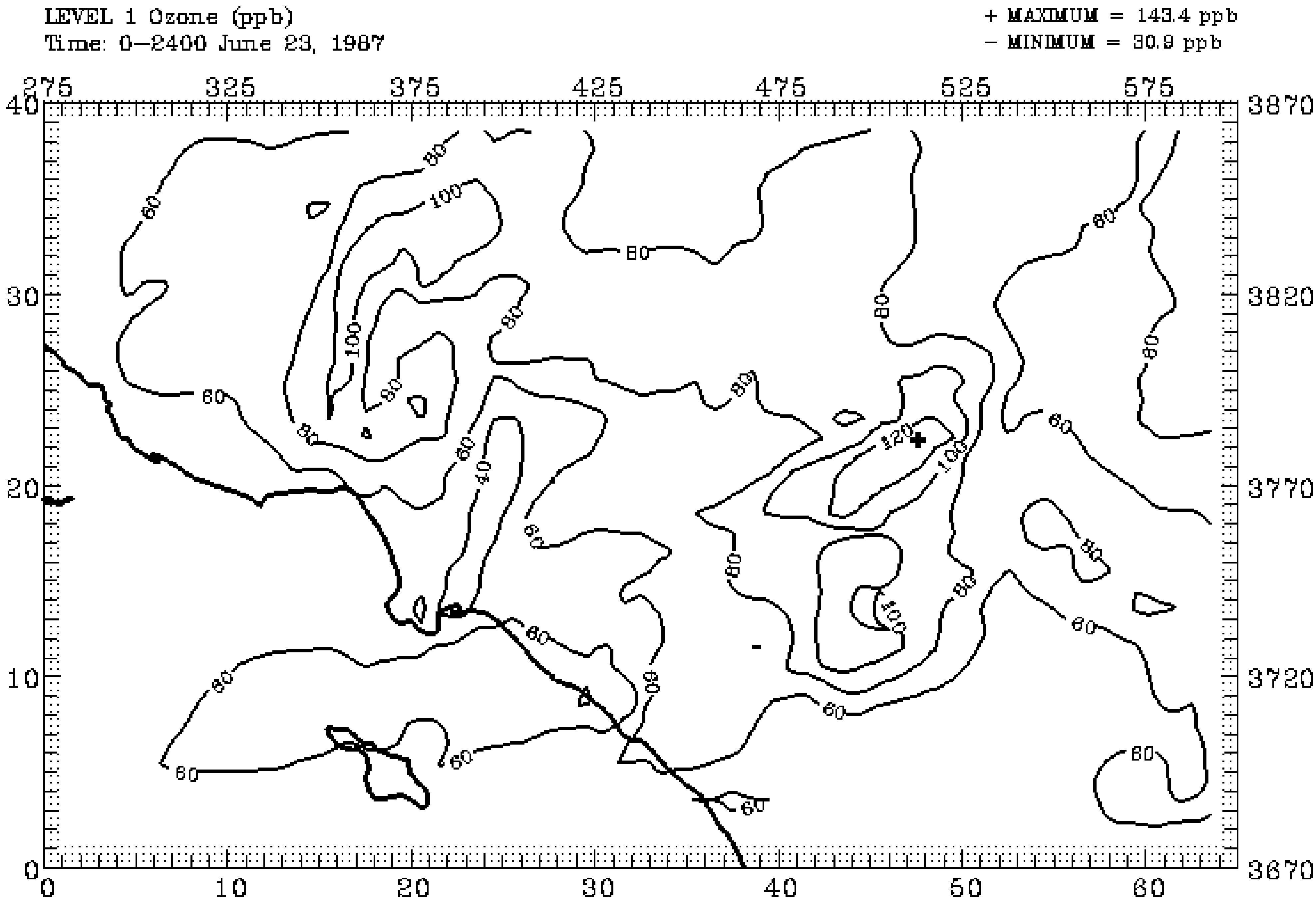


Figure 41a. Maximum simulated ozone concentrations with UAM/FCM for base year run with standard CB4 - June 23, 1987

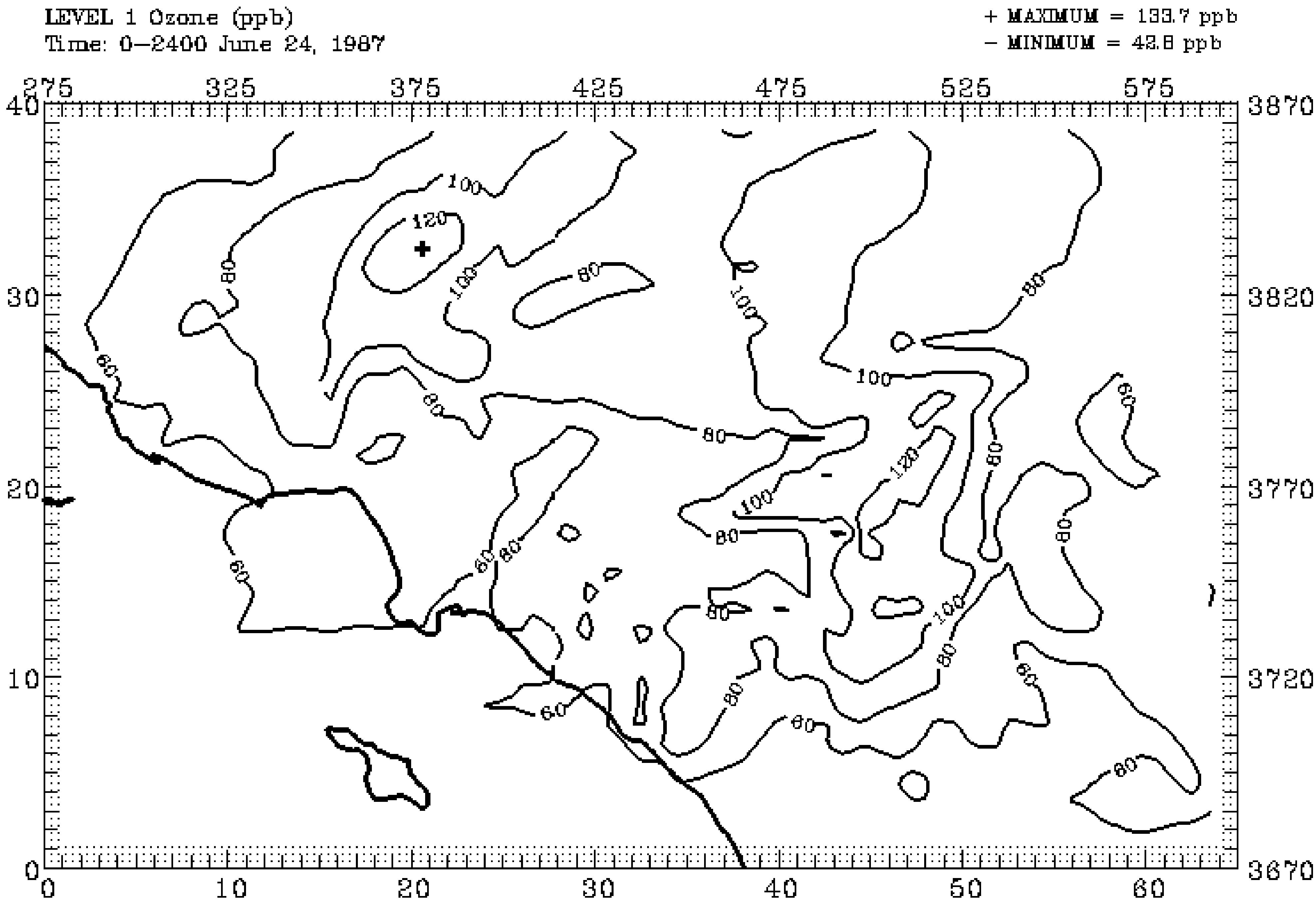


Figure 41b. Maximum simulated ozone concentrations with UAM/FXM for base year run with standard CB4 - June 24, 1987.

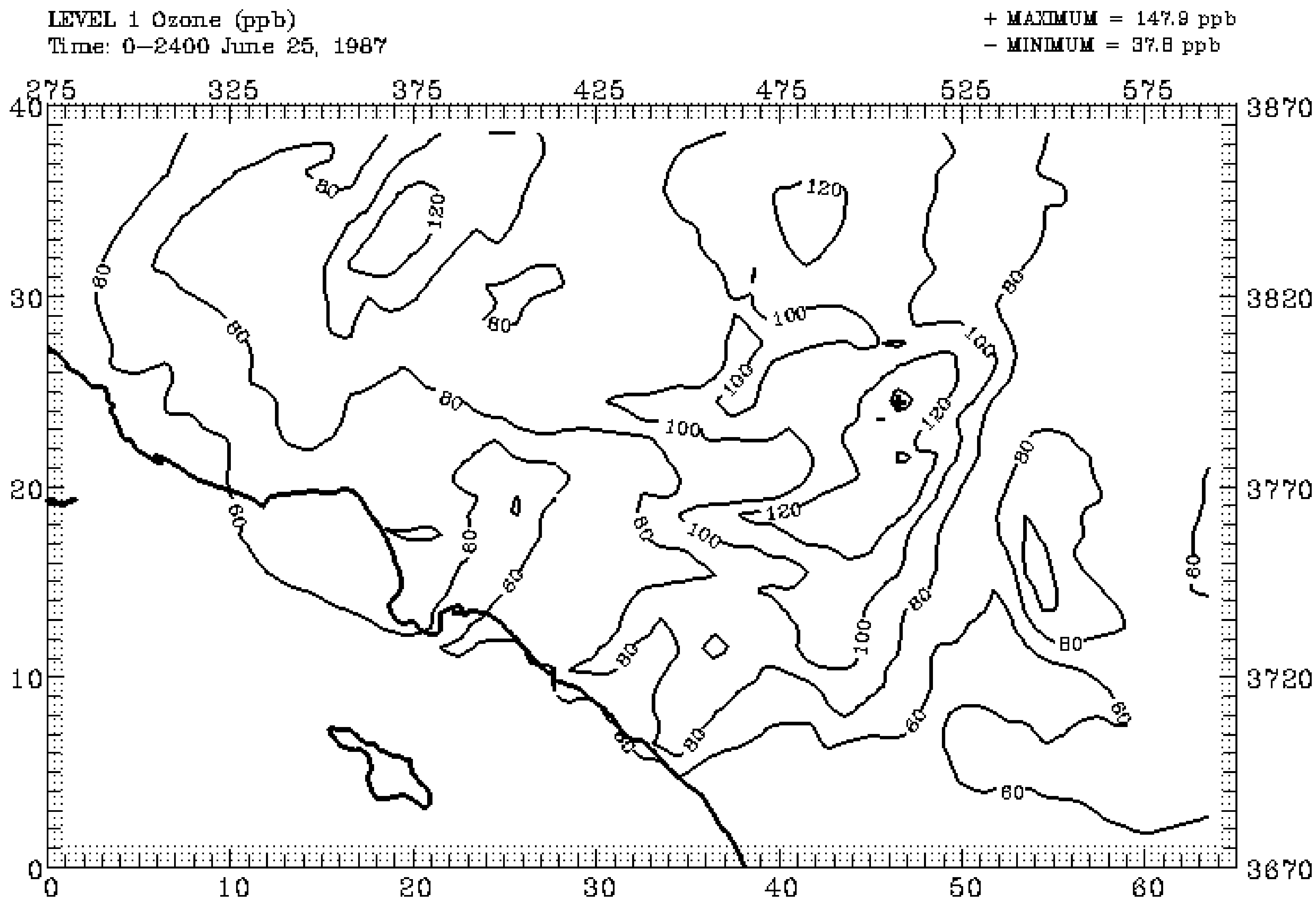


Figure 41c. Maximum simulated ozone concentrations with UAM/FCM for base year run with standard CB4 - June 25, 1987.

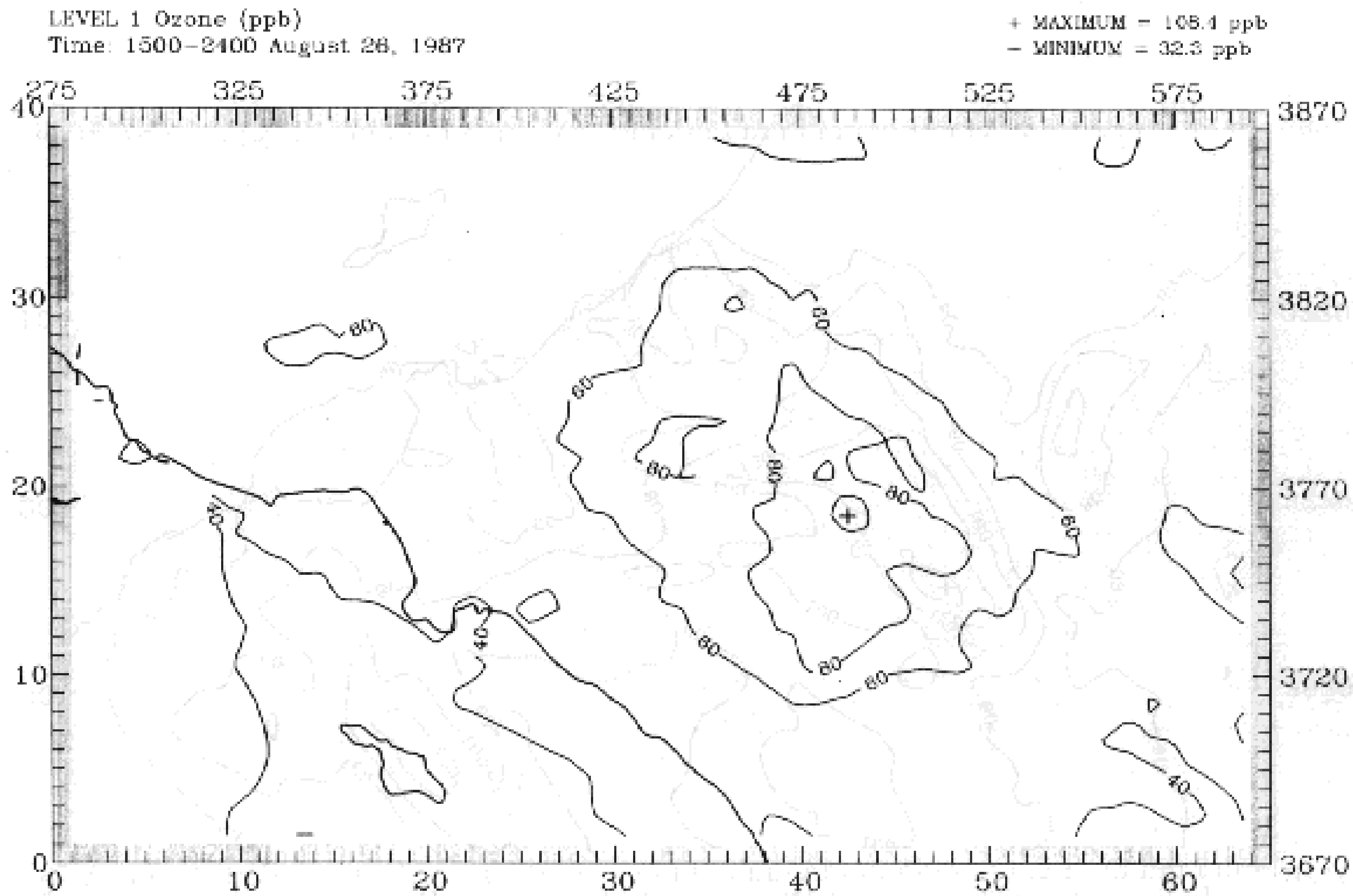


Figure 42a. Maximum simulated ozone concentrations with UAM/FCM for base year run with standard CB4 - August 26, 1987.

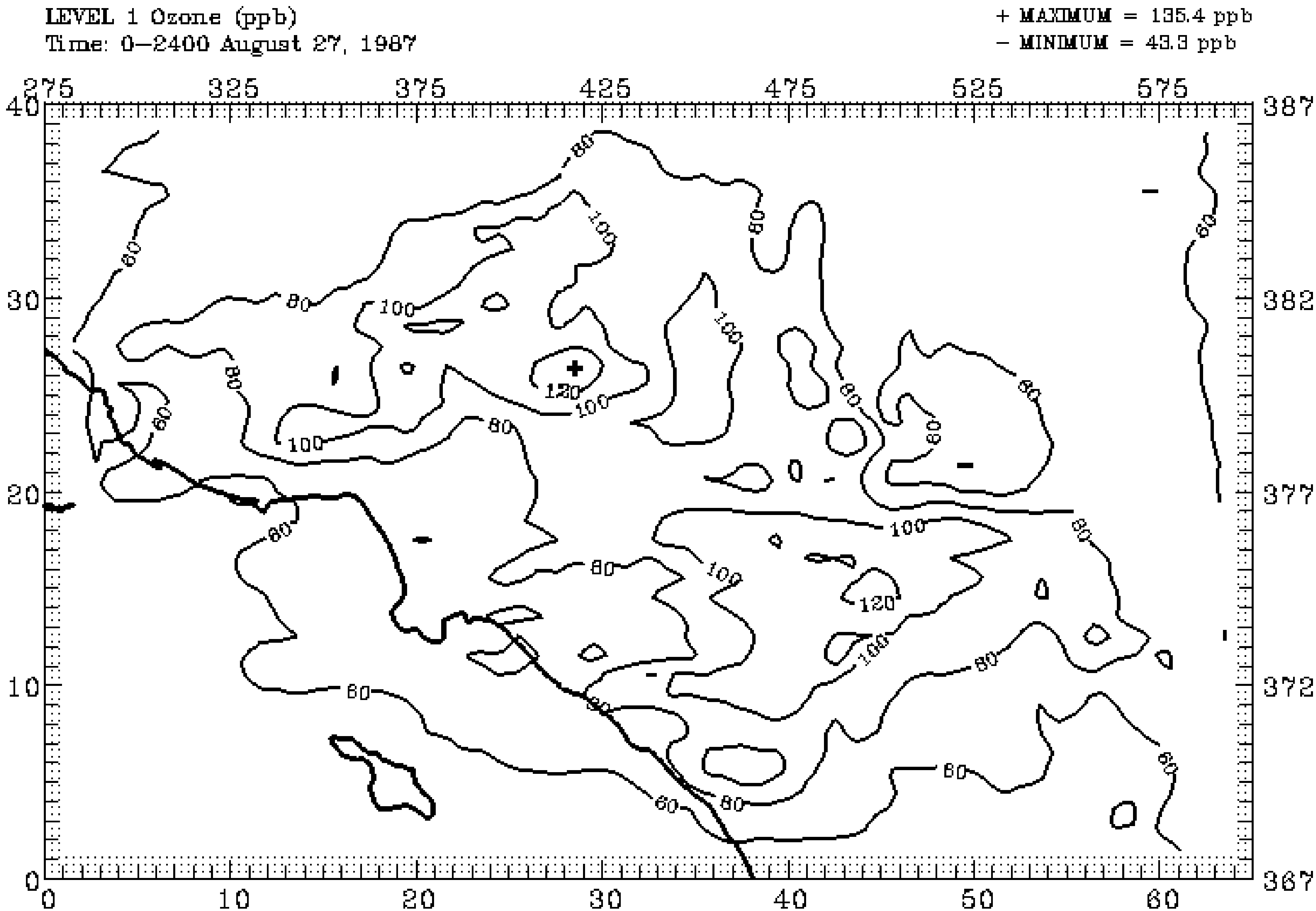


Figure 42b. Maximum simulated ozone concentrations with UAM/FCM for base year run with standard CB4 - August 27, 1987.

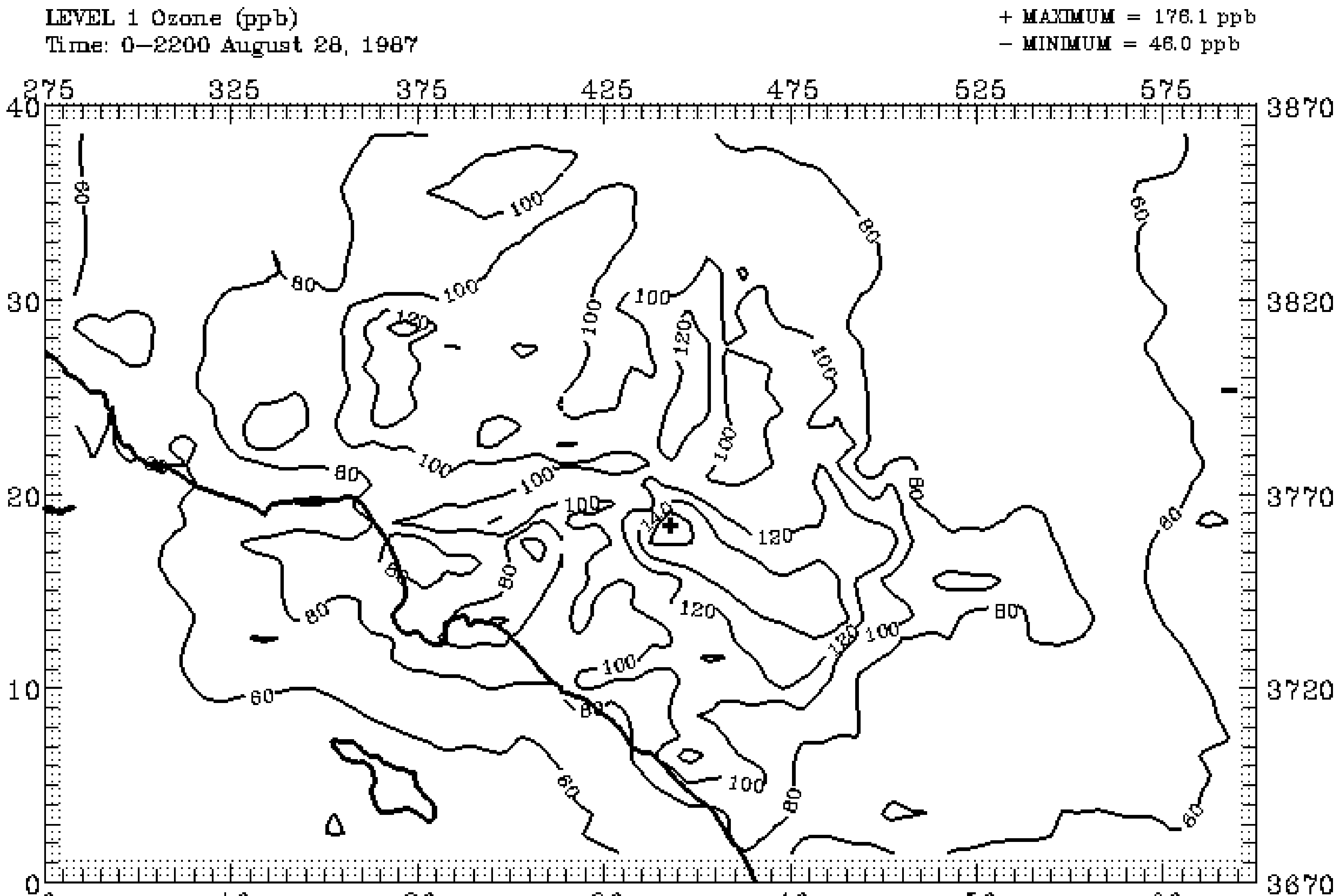


Figure 42c. Maximum simulated ozone concentrations with UAM/FCM for base year run with standard CB4 - August 28, 1987.

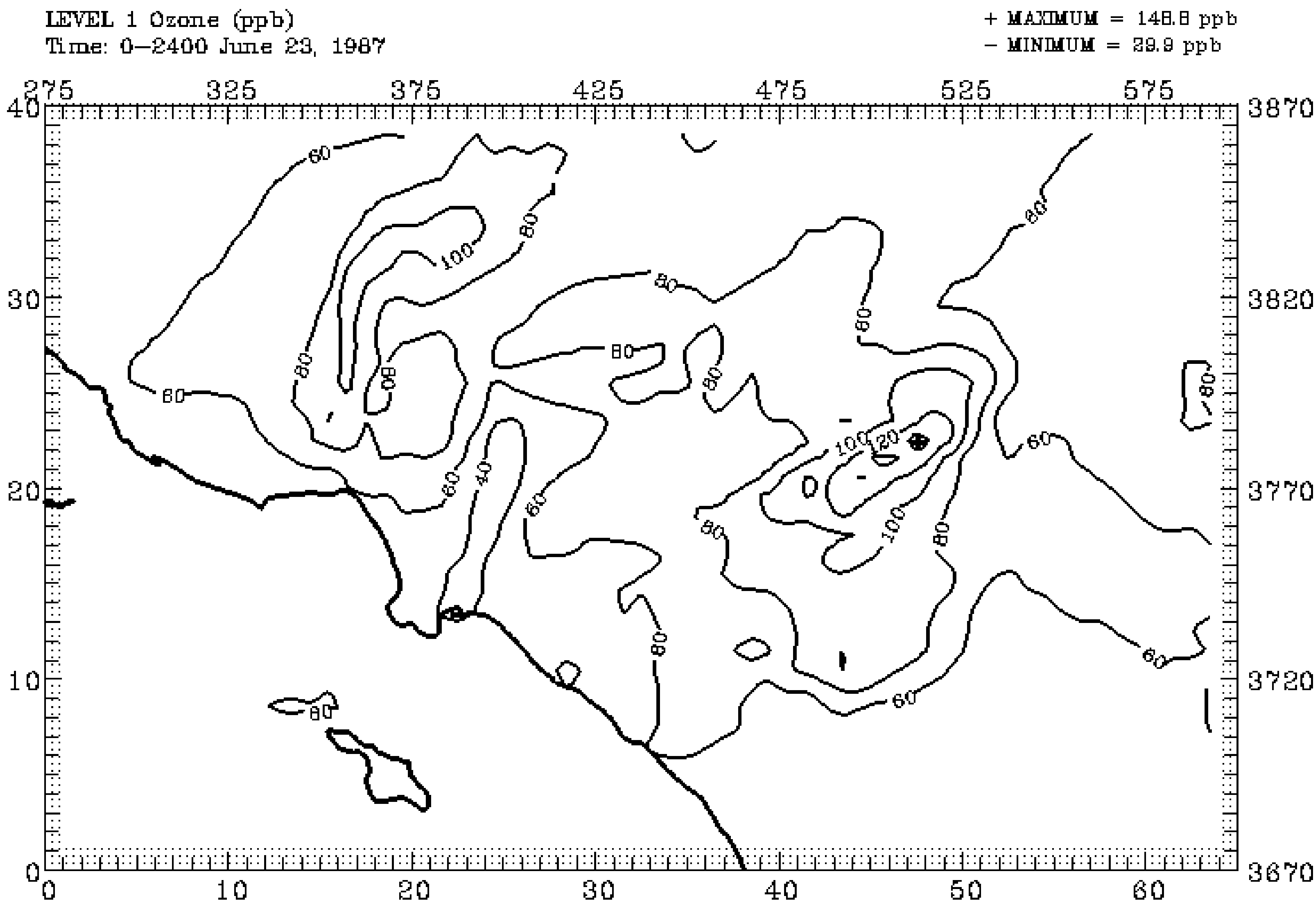


Figure 43a. Maximum simulated ozone concentrations with UAM/FCM for base year run with highflux CB4 - June 23, 1987.

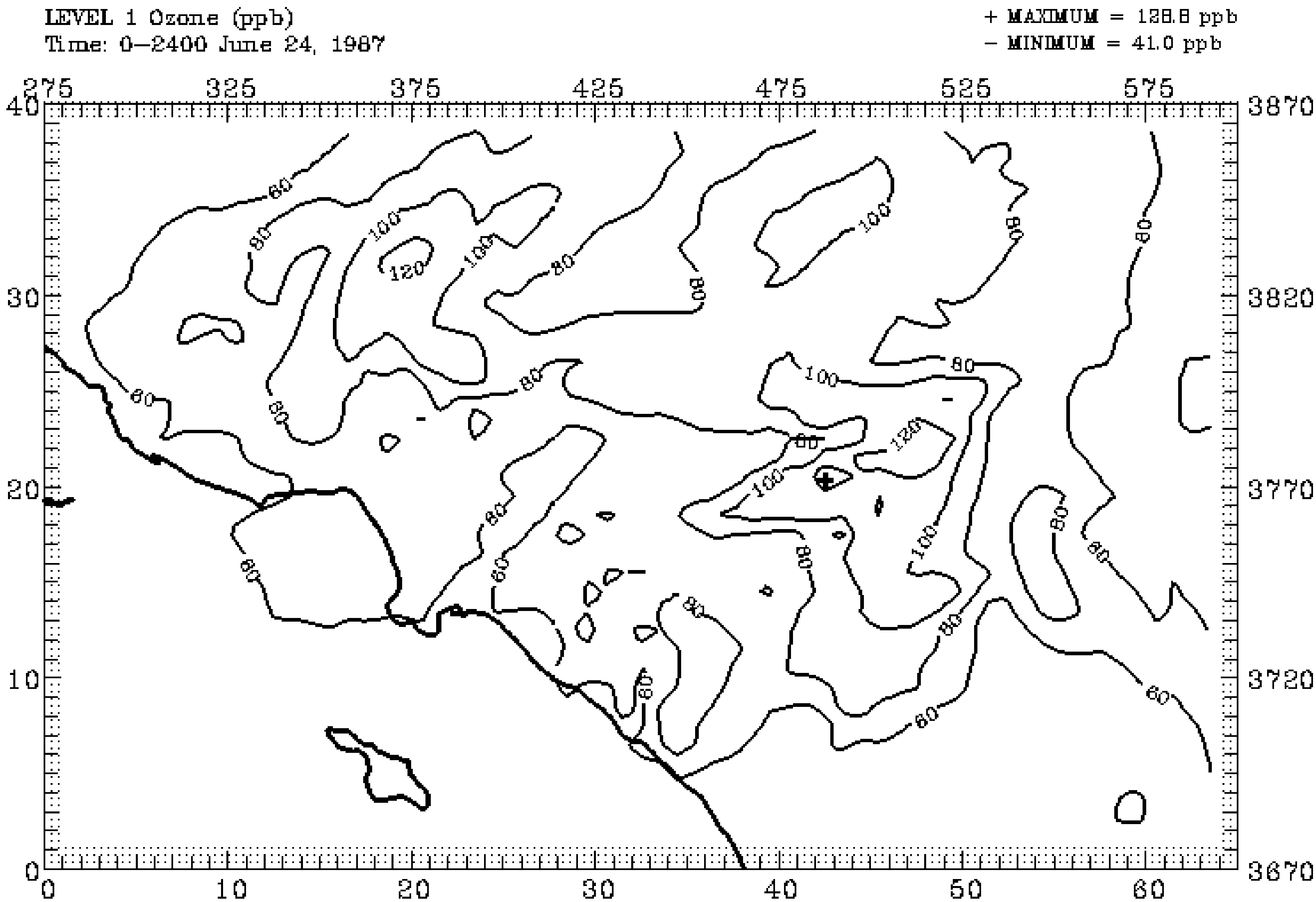


Figure 43b. Maximum simulated ozone concentrations with UAM/FCM for base year run with highflux CB4 - June 24, 1987.

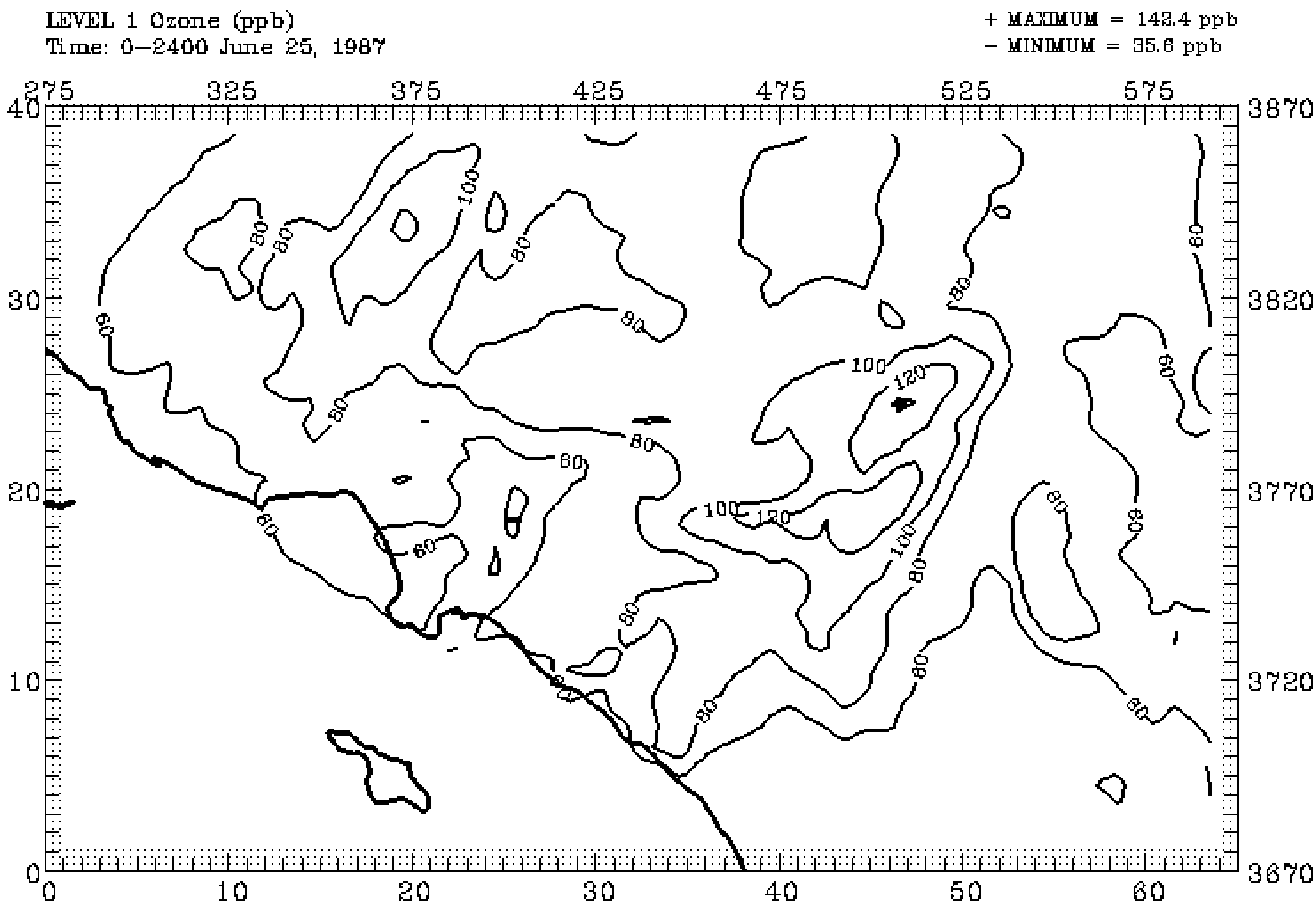


Figure 43c. Maximum simulated ozone concentrations with UAM/FCM for base year run with highflux CB4 - June 25, 1987.

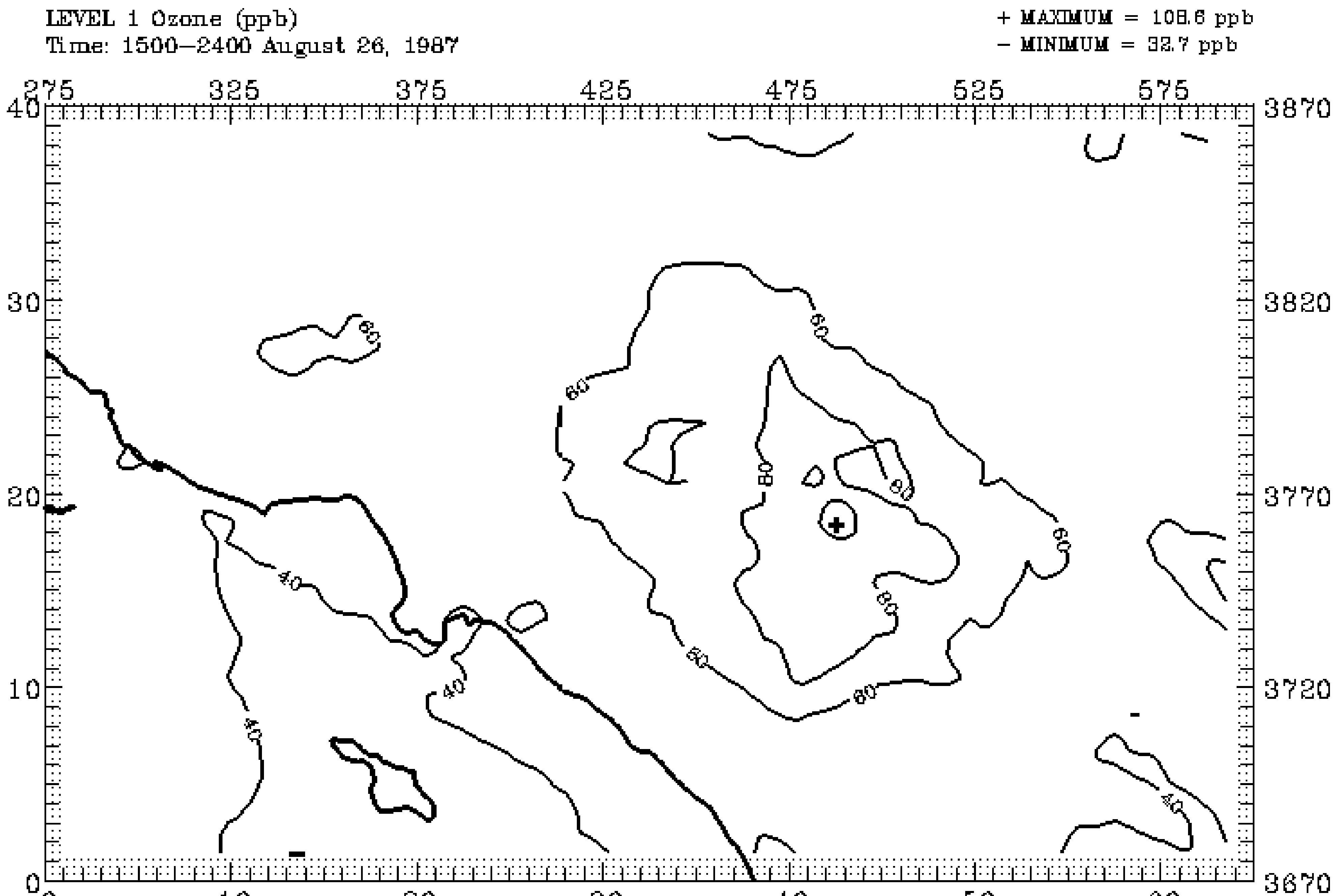


Figure 44a. Maximum simulated ozone concentrations with UAM/FCM for base year run with highflux CB4 - August 26, 1987.

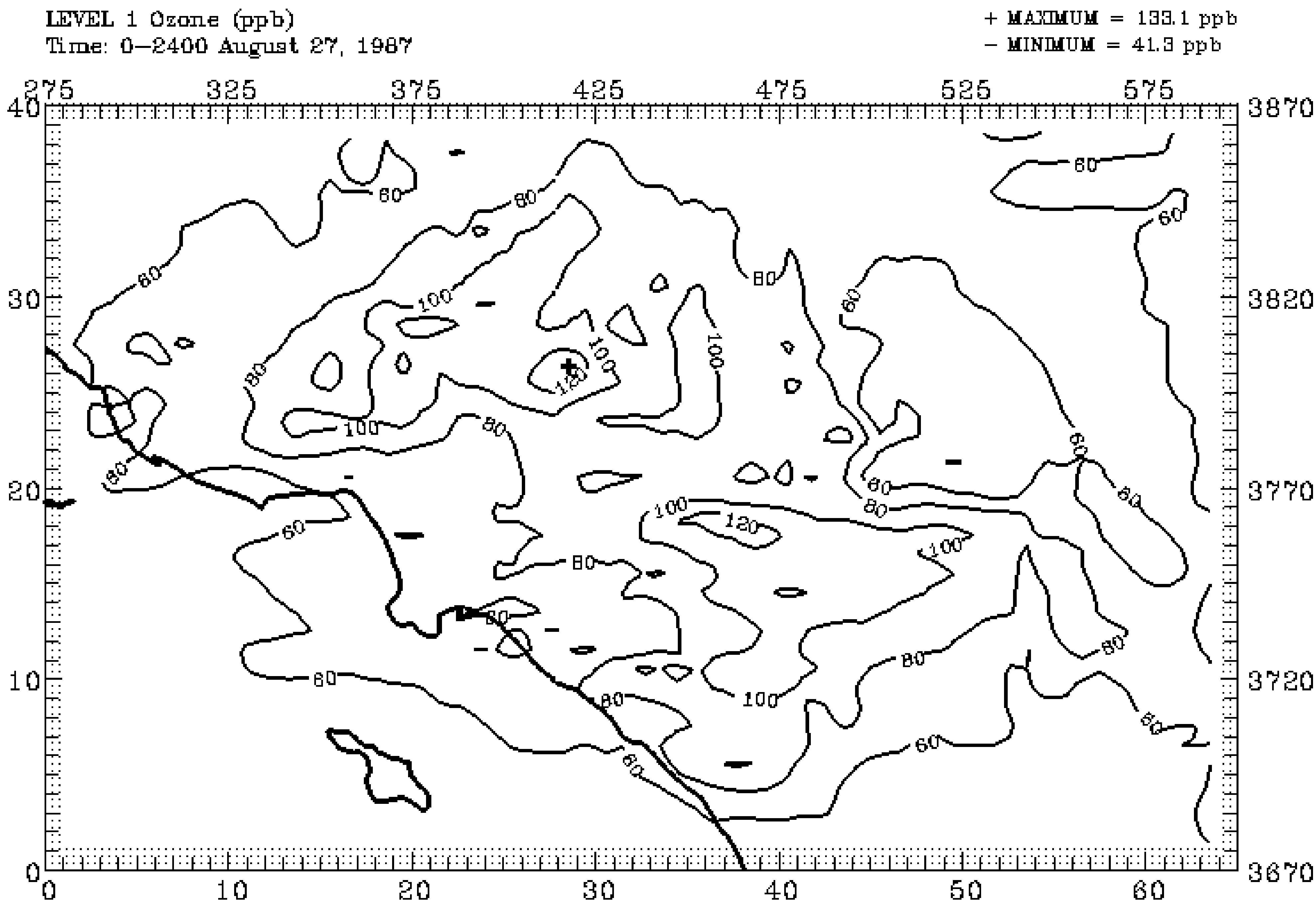


Figure 44b. Maximum simulated ozone concentrations with UAM/FCBM for base year run with highflux CB4 - August 27, 1987.

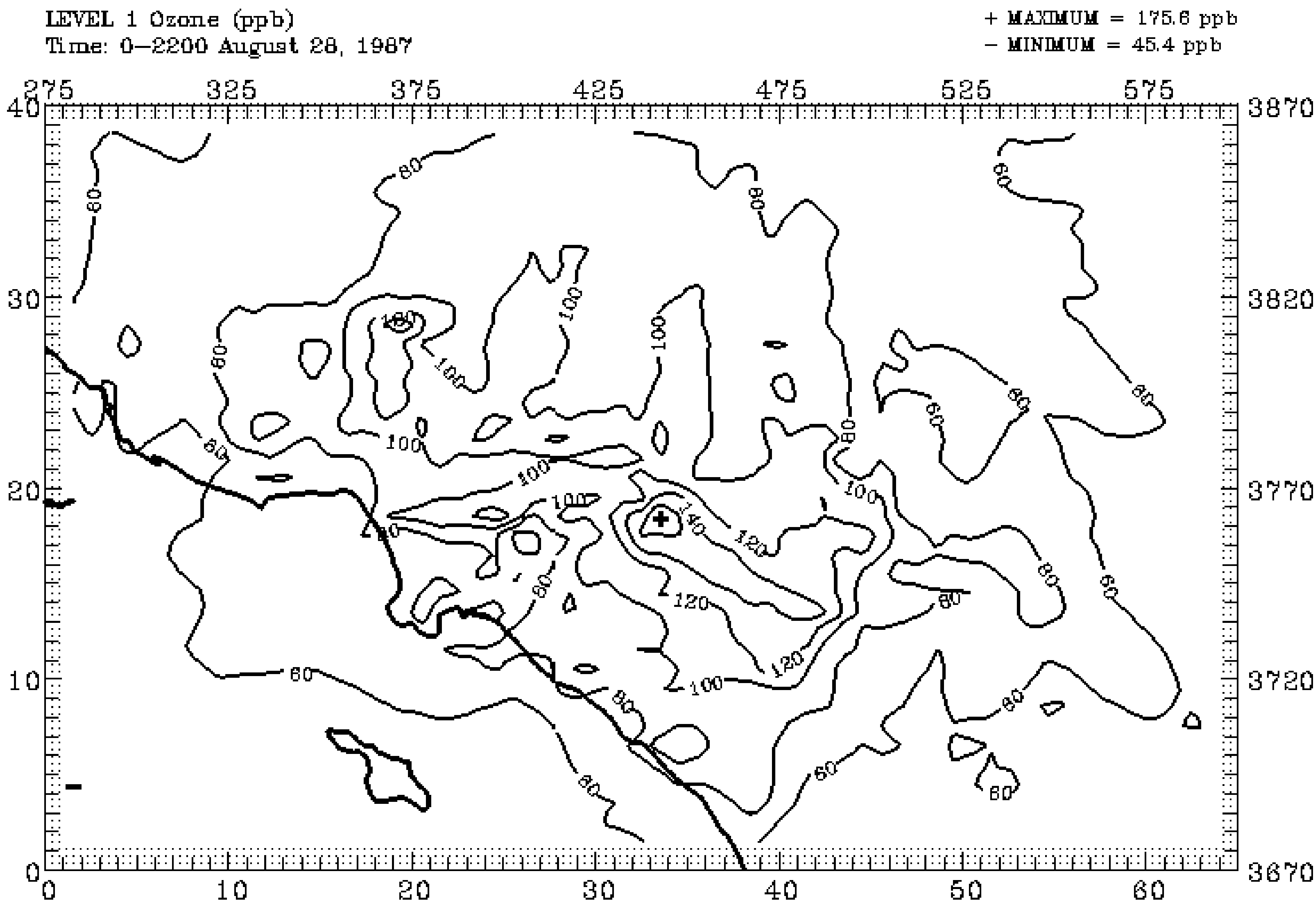


Figure 44c. Maximum simulated ozone concentrations with UAM/FCM for base year run with highflux CB4 - August 28, 1987.

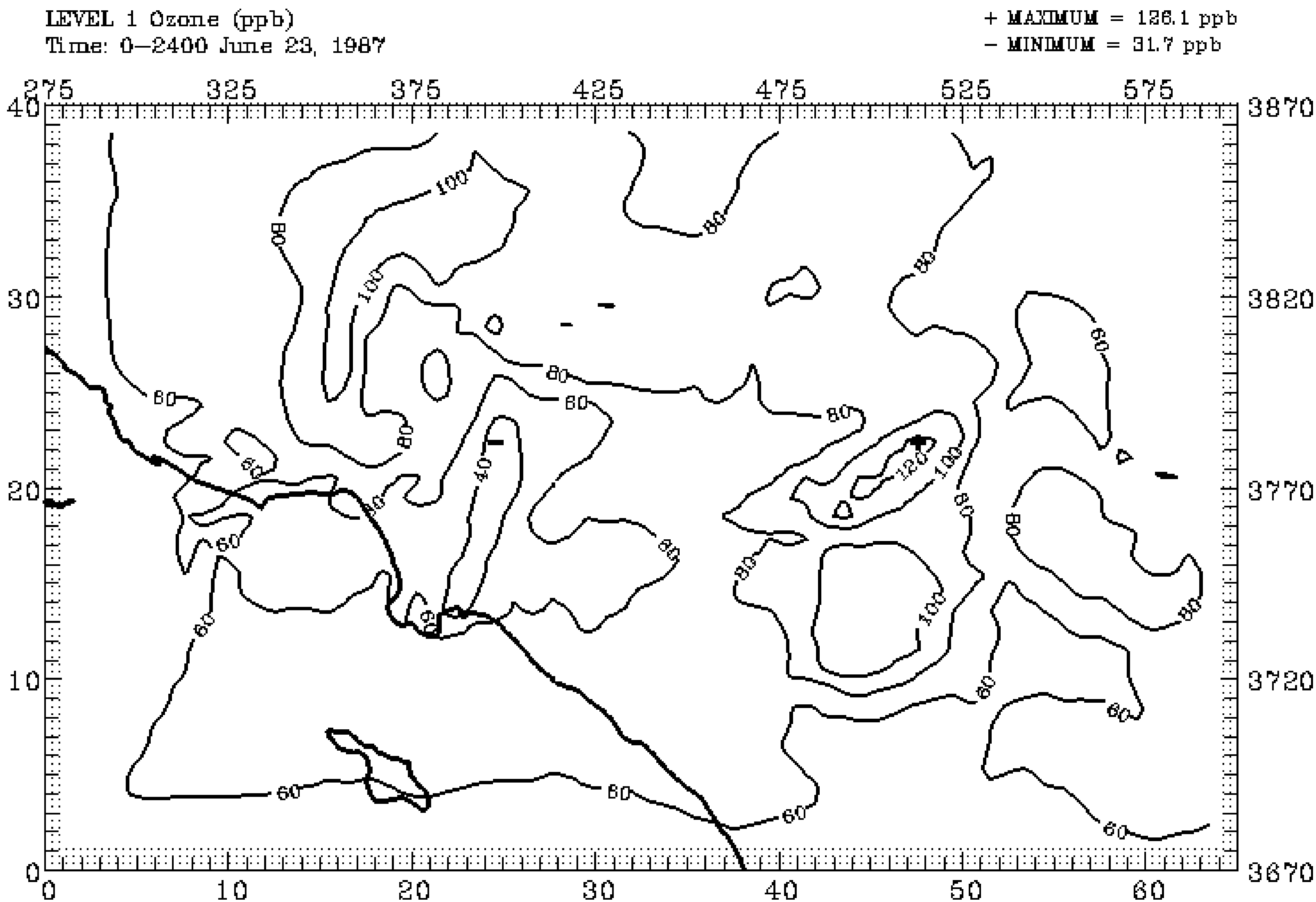


Figure 45a. Maximum simulated ozone concentrations with UAM/FCM for base year run with lowflux CB4 - June 23, 1987.

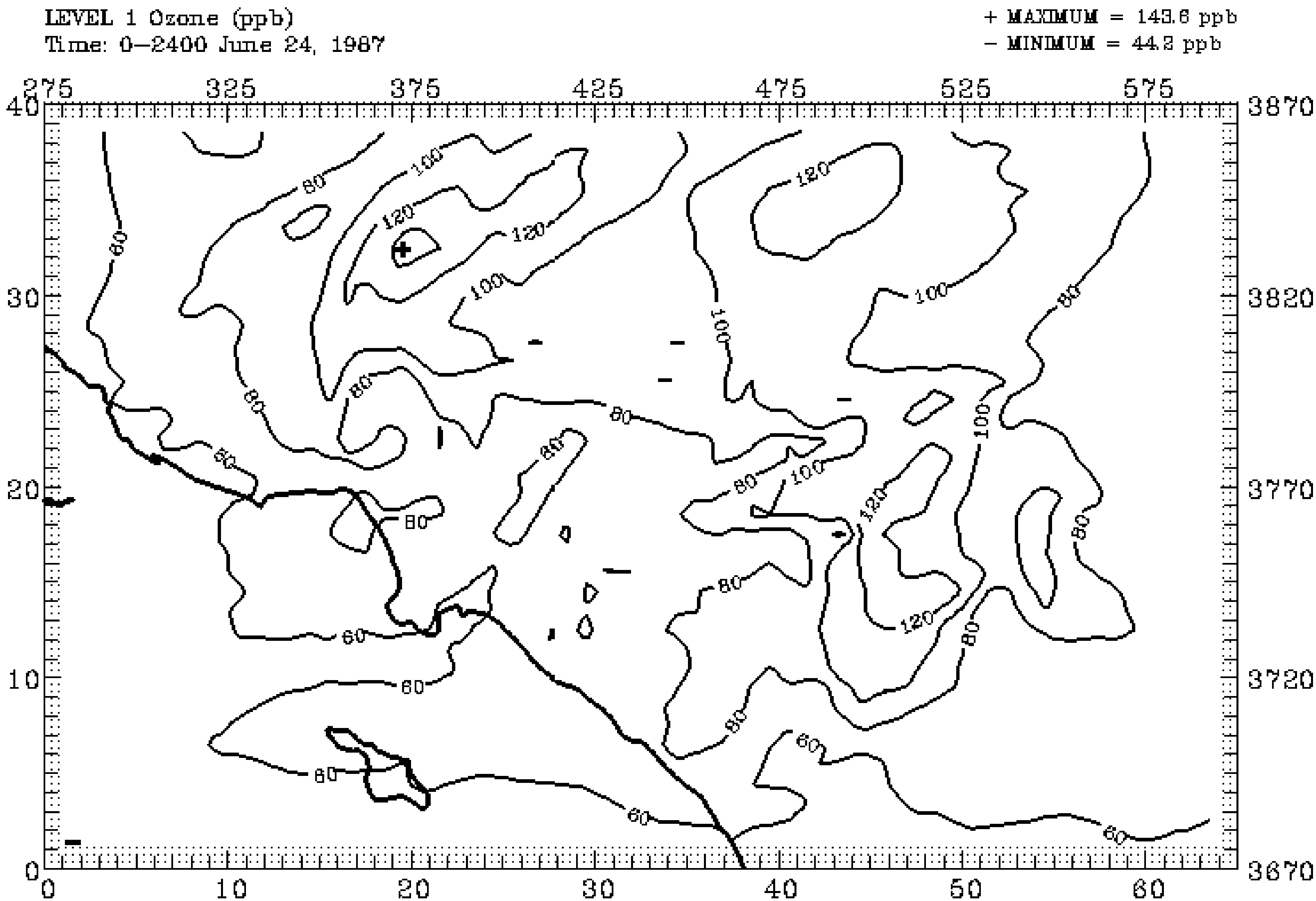


Figure 45b. Maximum simulated ozone concentrations with UAM/FCM for base year run with lowflux CB4 - June 24, 1987.

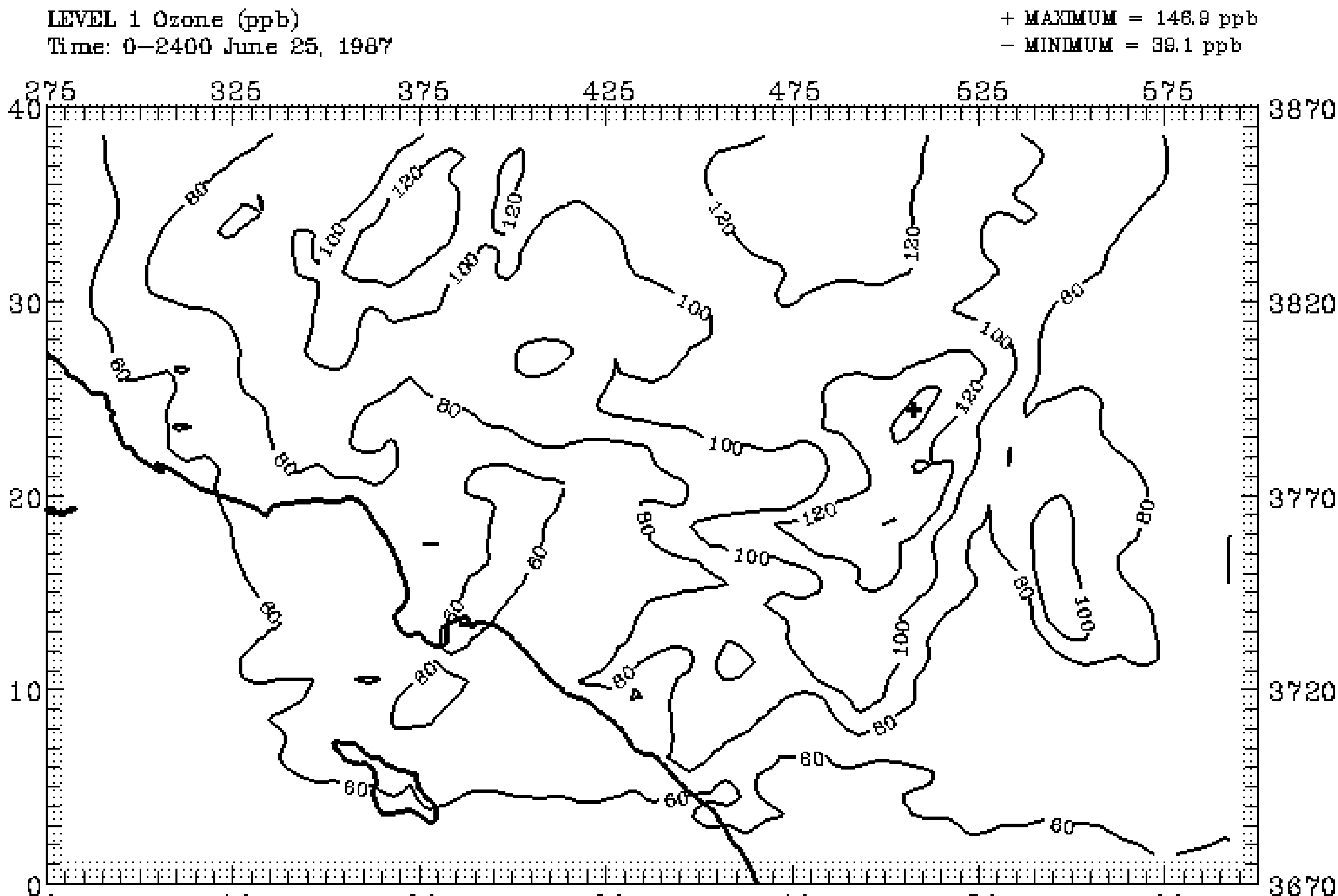


Figure 45c. Maximum simulated ozone concentrations with UAM/FCM for base year run with lowflux CB4 - June 25, 1987.

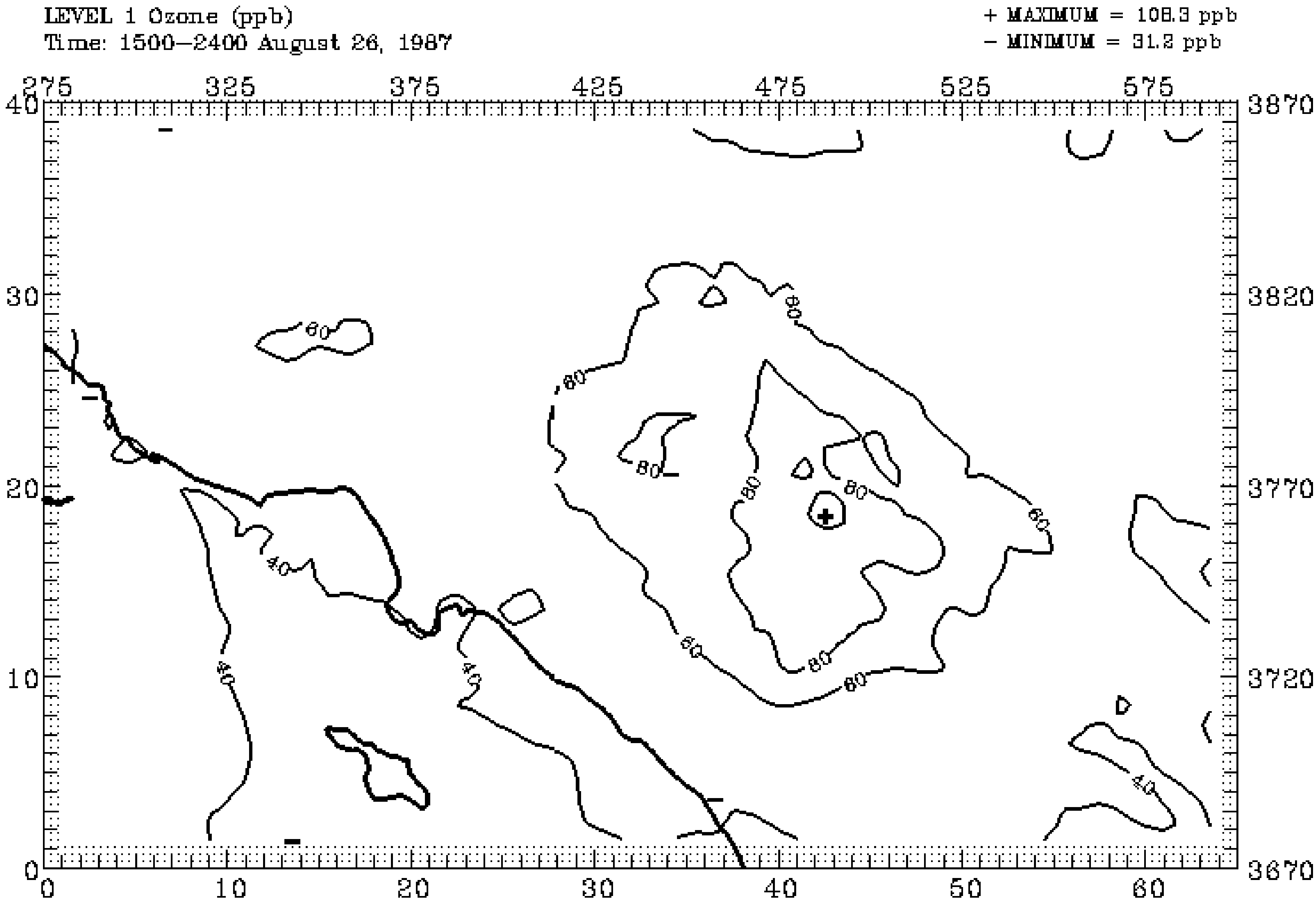


Figure 46a. Maximum simulated ozone concentrations with UAM/FCM for base year run with lowflux CB4 - August 26, 1987.

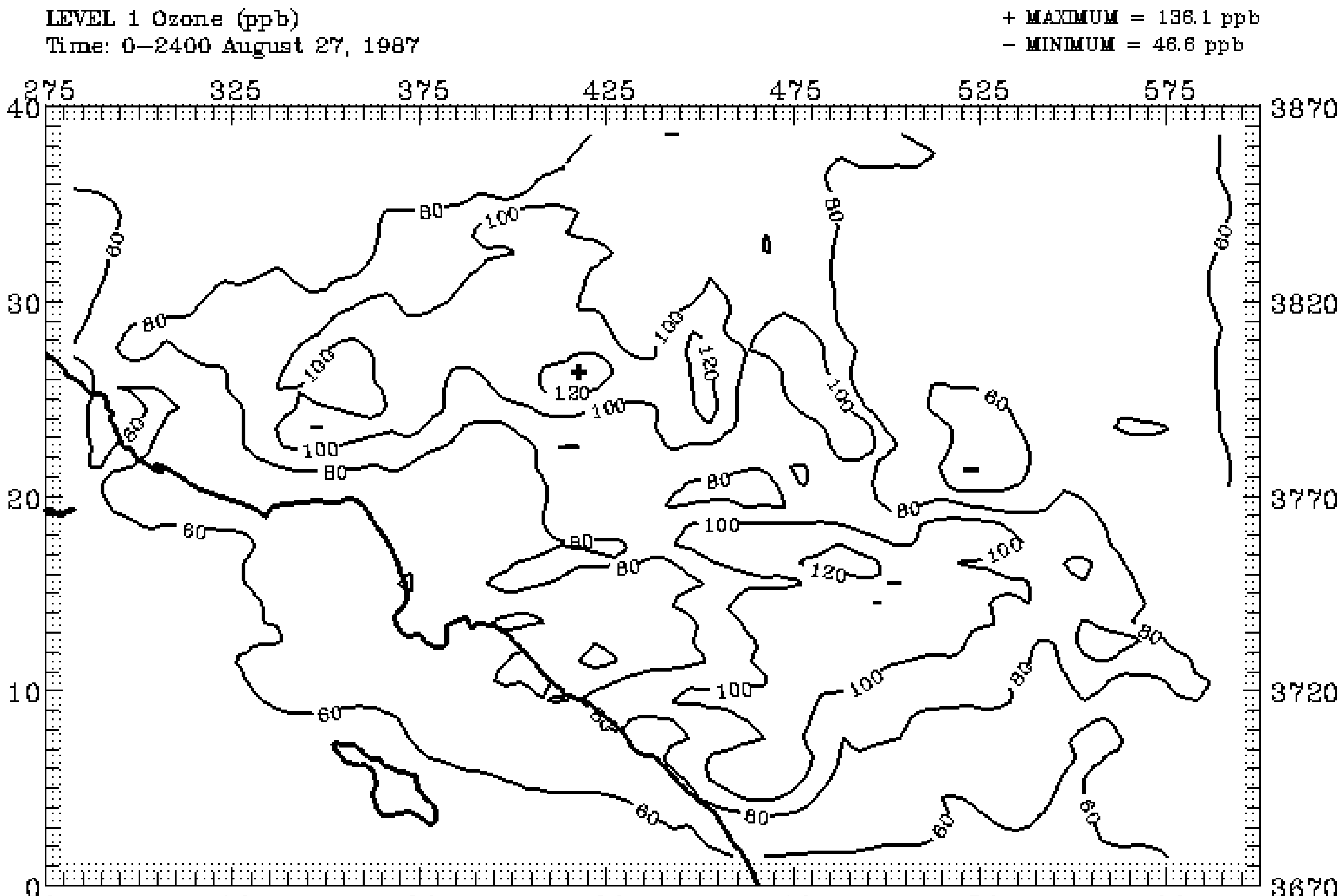


Figure 46b. Maximum simulated ozone concentrations with UAM/FCM for base year run with lowflux CB4 - August 27, 1987.

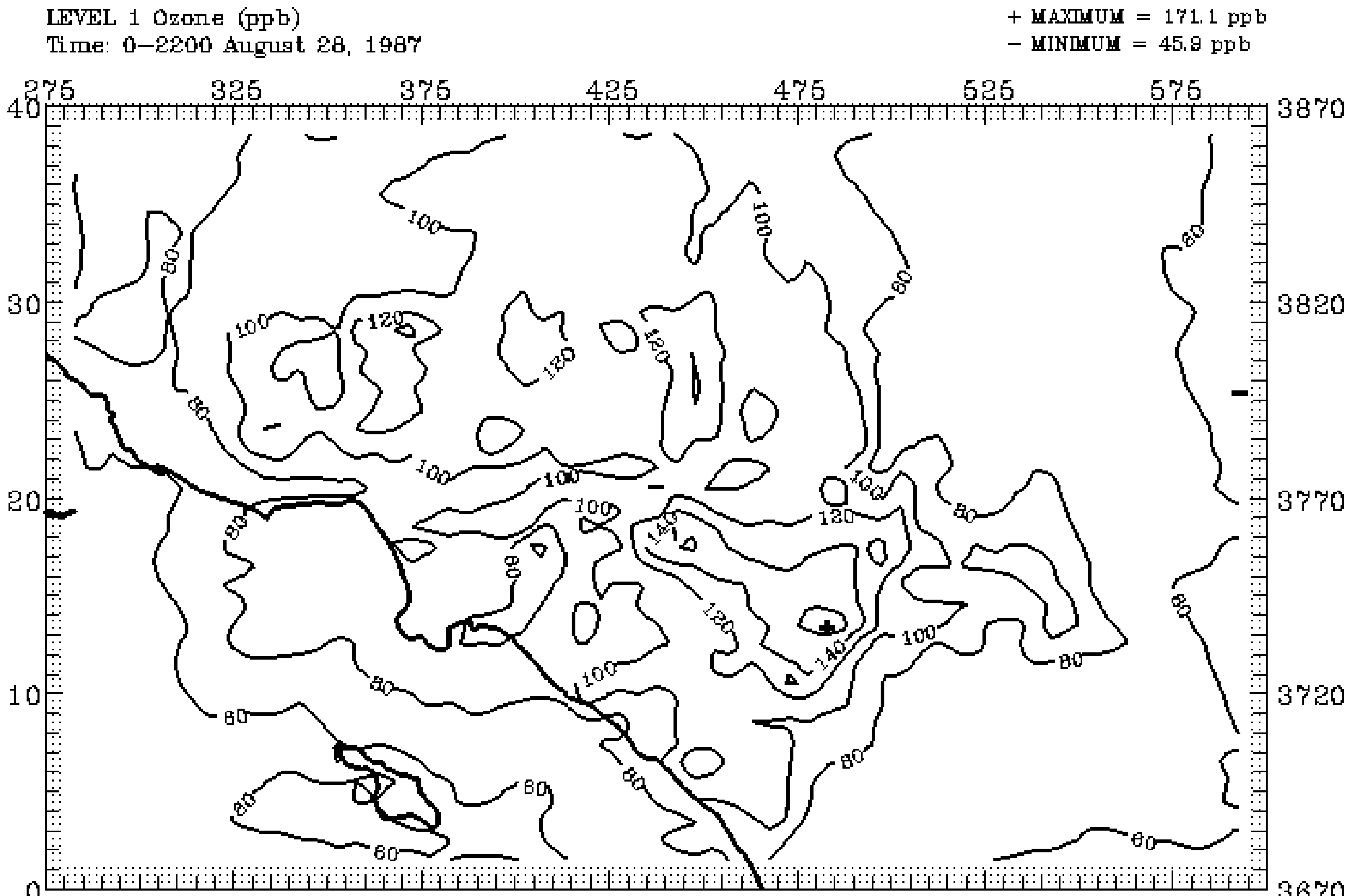


Figure 46c. Maximum simulated ozone concentrations with UAM/FCM for base year run with lowflux CB4 - August 28, 1987.

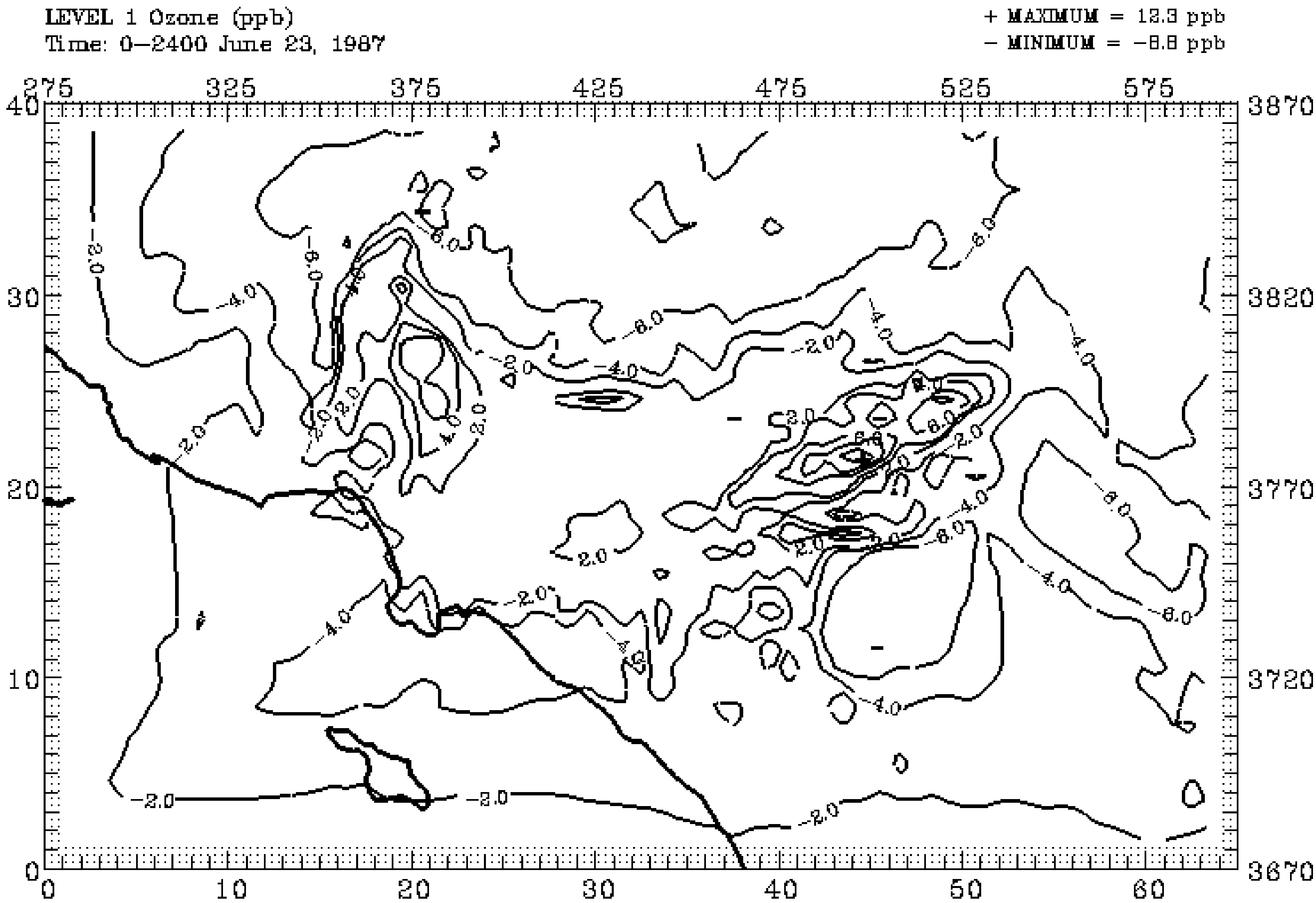


Figure 47a. Difference in maximum simulated ozone concentrations with UAM/FMC between highflux and stdcb4 for base year run - June 23, 1987.

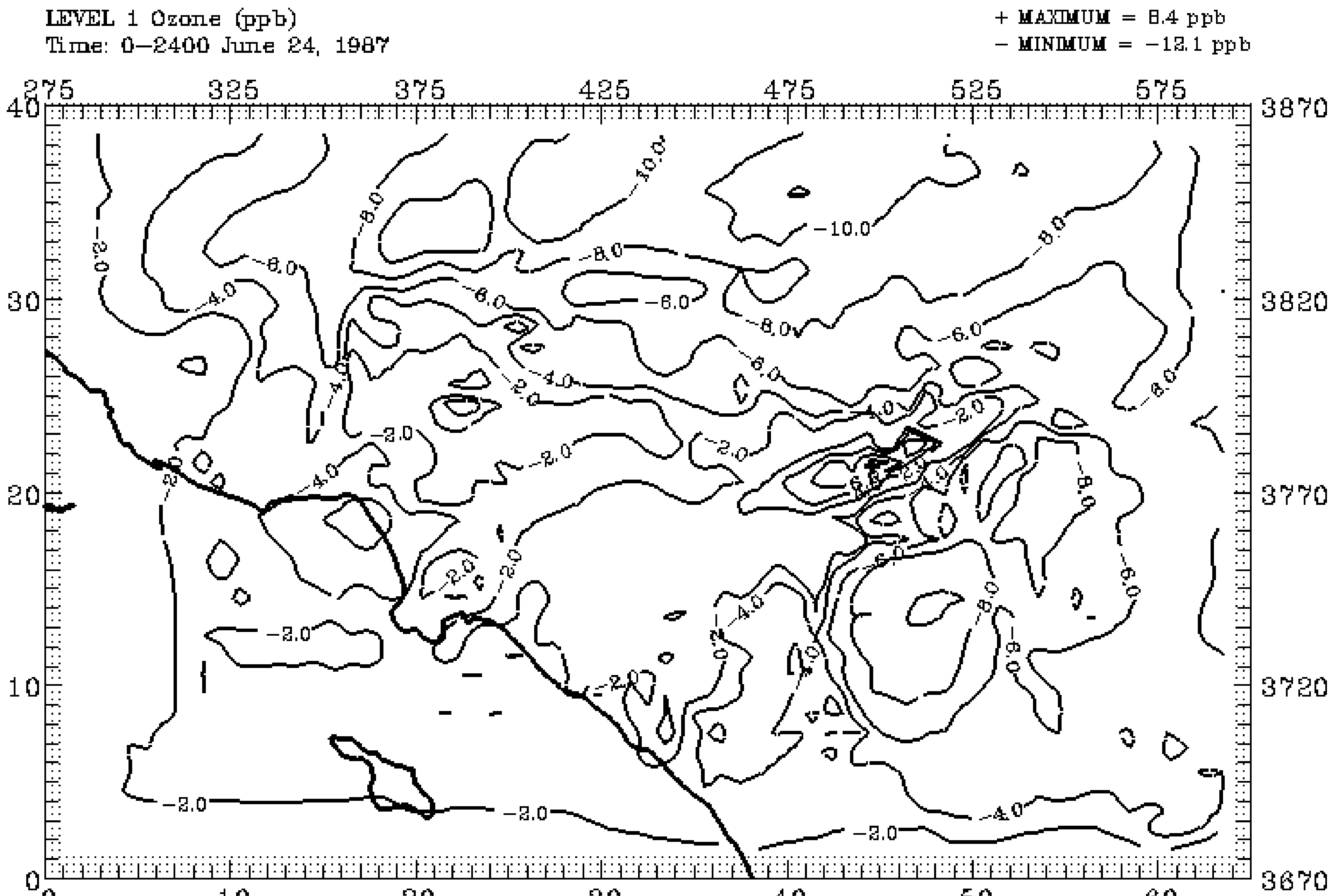


Figure 47b. Difference in maximum simulated ozone concentrations with UAM/FMC between highflux and stdcb4 for base year run - June 24, 1987.

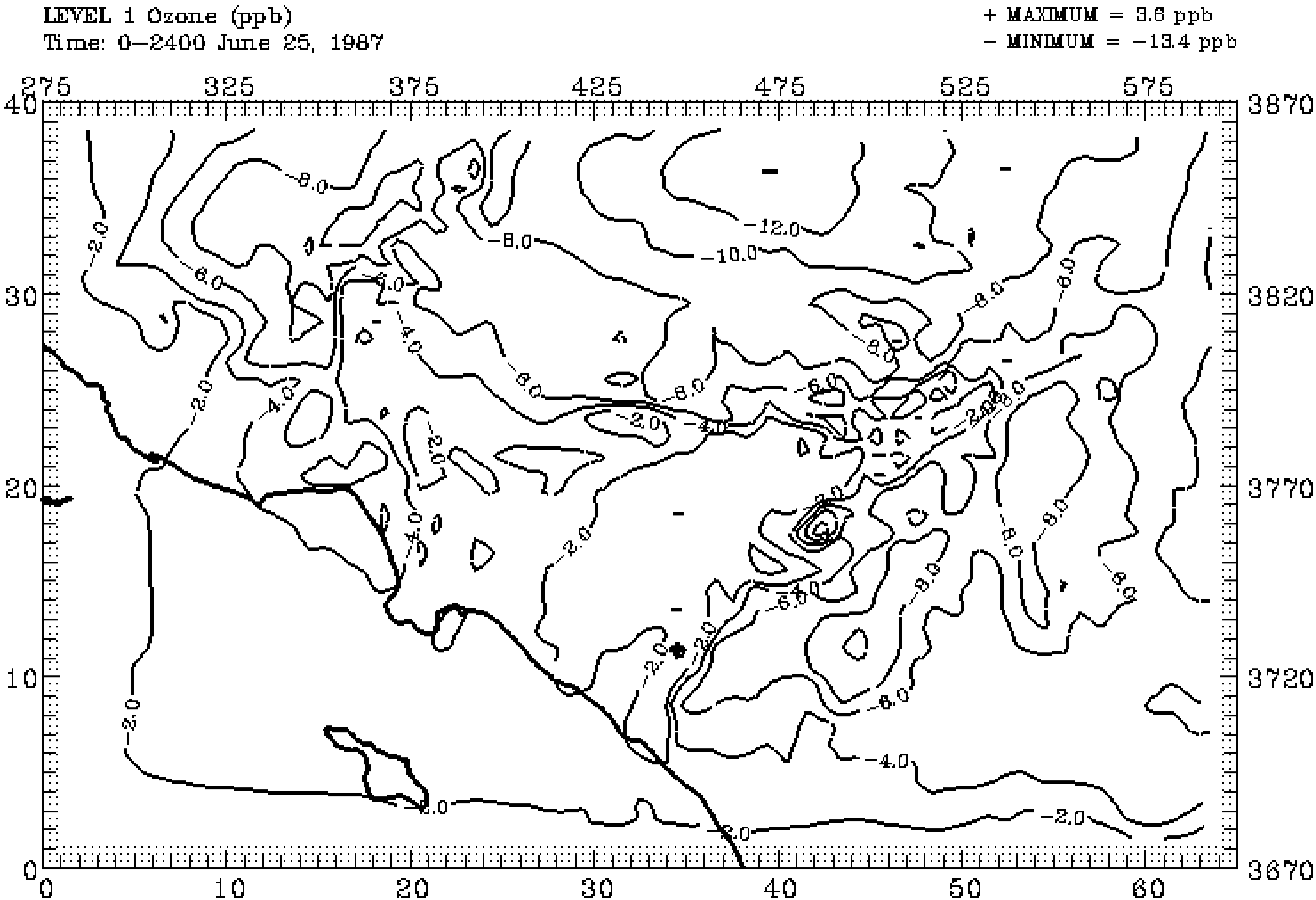


Figure 47c. Difference in maximum simulated ozone concentrations with UAM/FMC between highflux and stdcb4 for base year run - June 25, 1987.

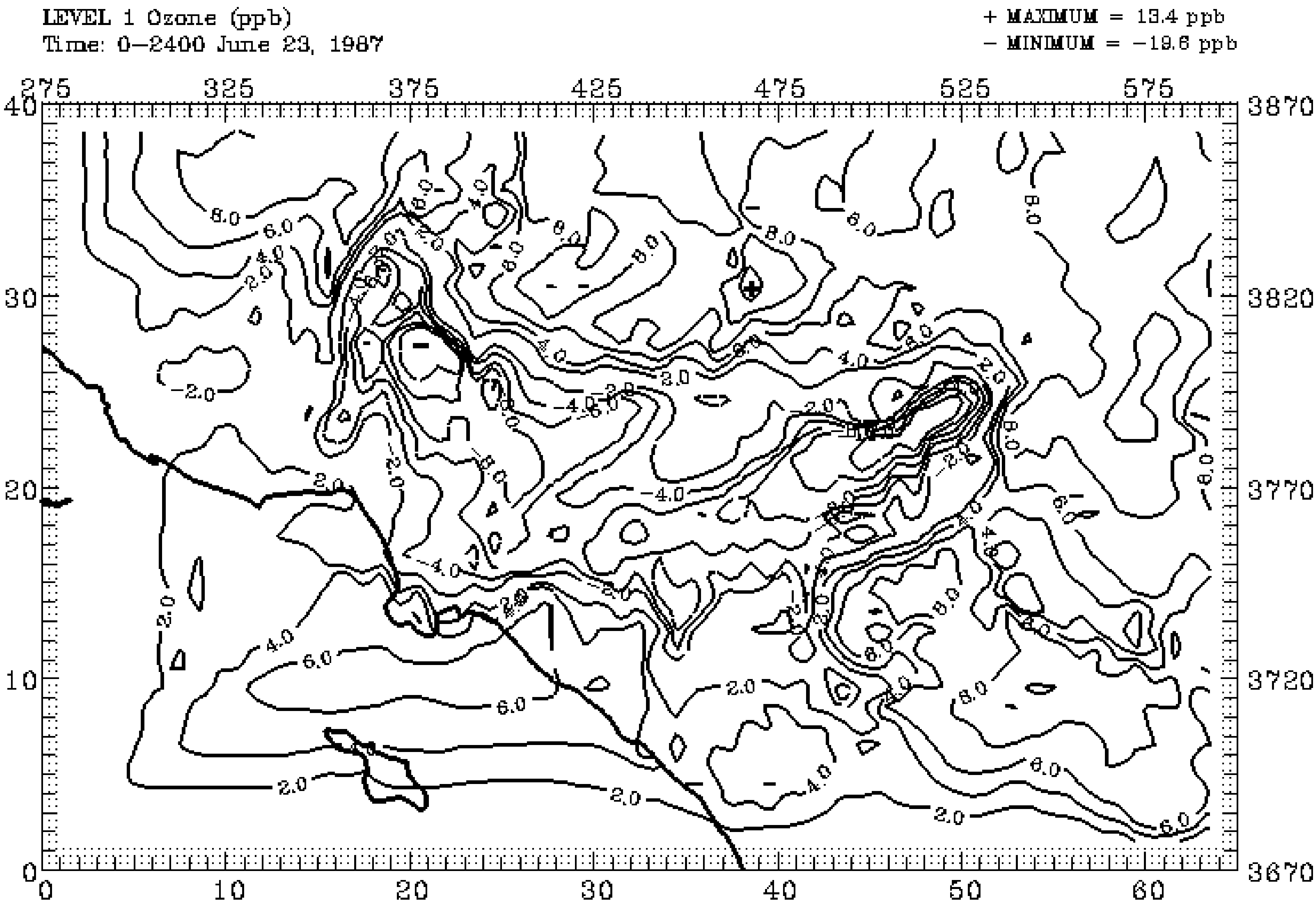


Figure 48a. Difference in maximum simulated ozone concentrations with UAM/FCM between lowflux and stdcb4 for base year run - June 23, 1987.

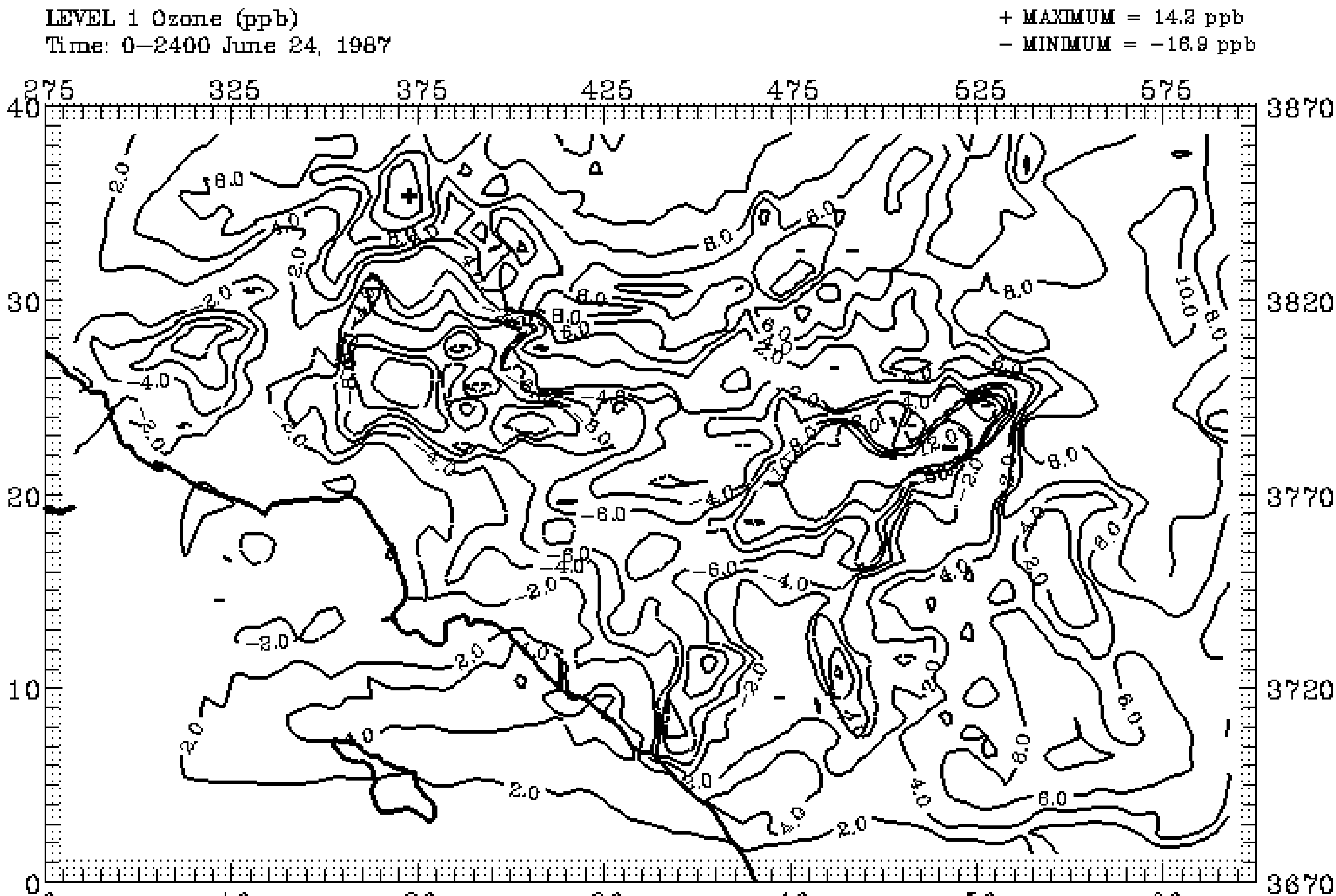


Figure 48b. Difference in maximum simulated ozone concentrations with UAM/FCM between lowflux and stdcb4 for base year run - June 24, 1987.

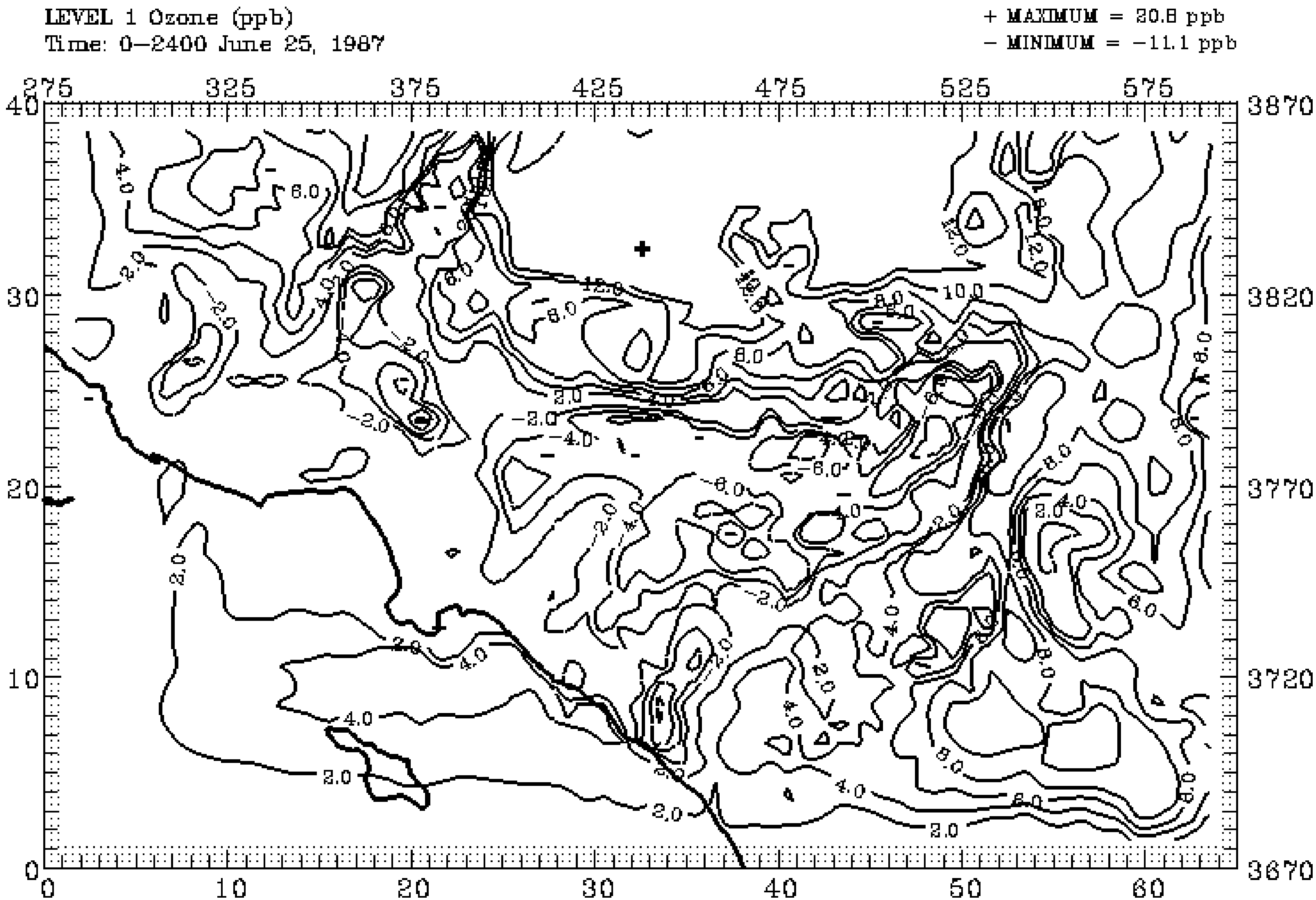


Figure 48c. Difference in maximum simulated ozone concentrations with UAM/FCM between lowflux and stdcb4 for base year run - June 25, 1987.

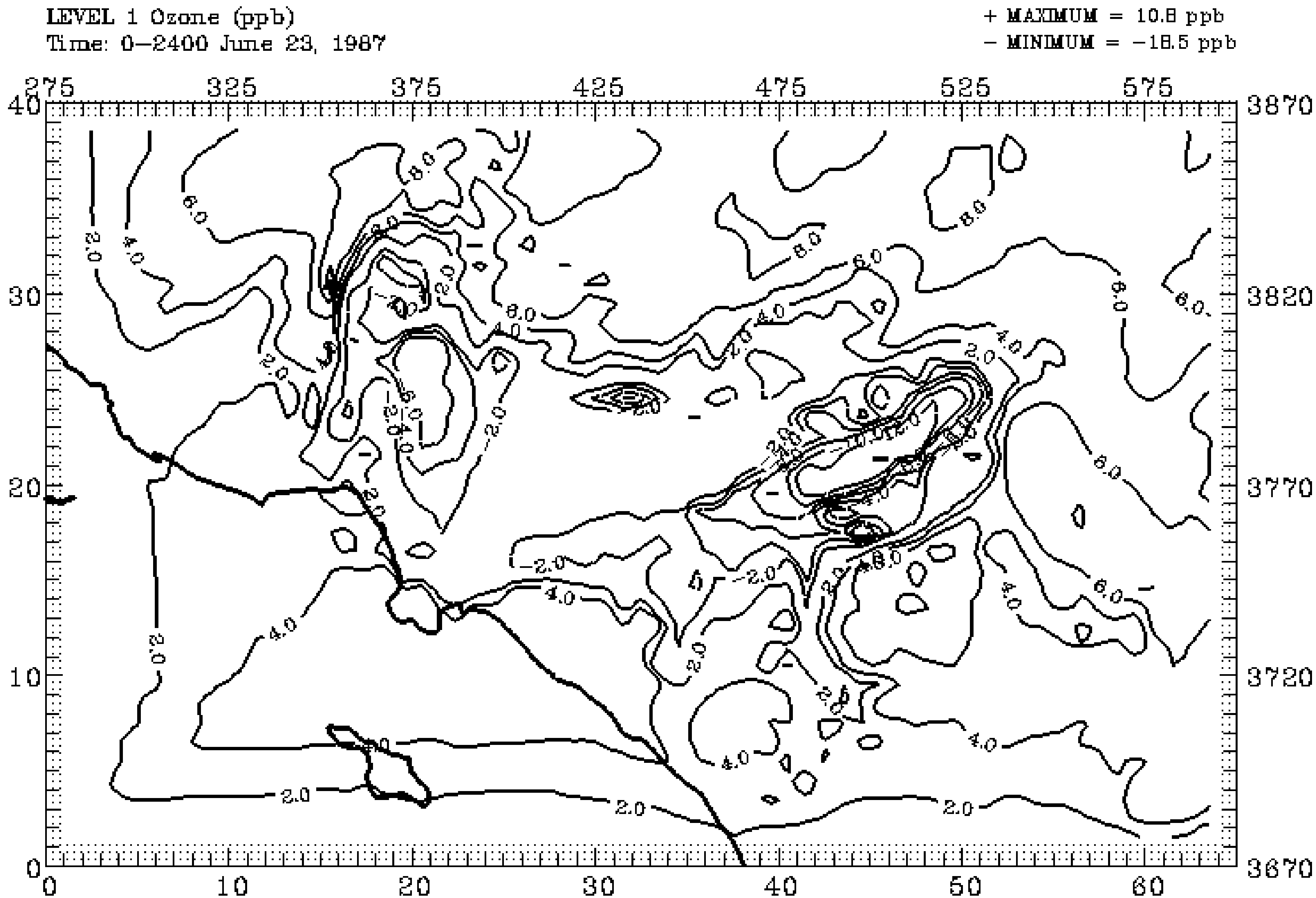


Figure 49a. Difference in maximum simulated ozone concentrations with UAM/FCM between highflux and stdcb4 for base year run - August 26, 1987.

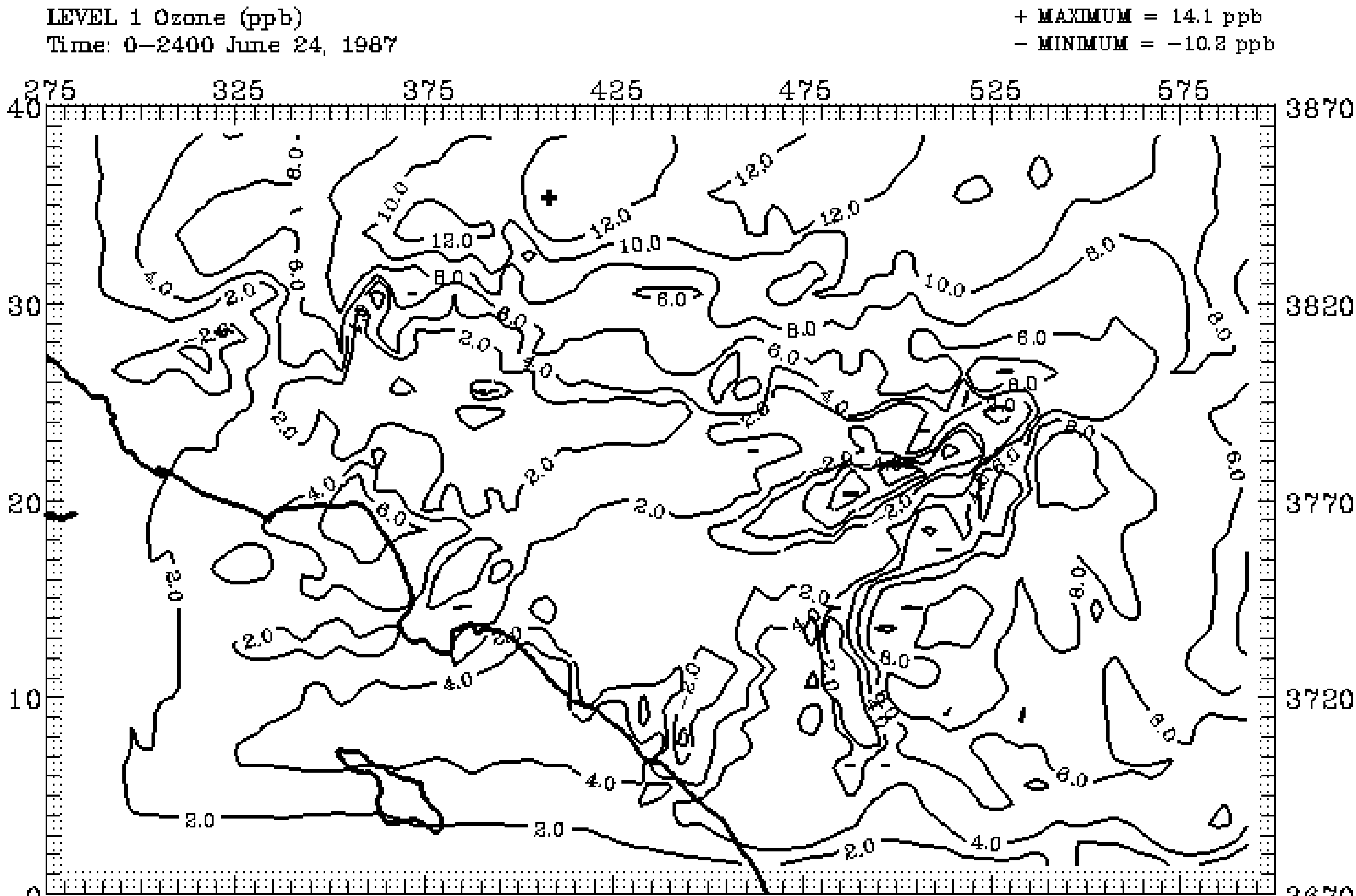


Figure 49b. Difference in maximum simulated ozone concentrations with UAM/FCM between highflux and stdcb4 for base year run - August 27, 1987.

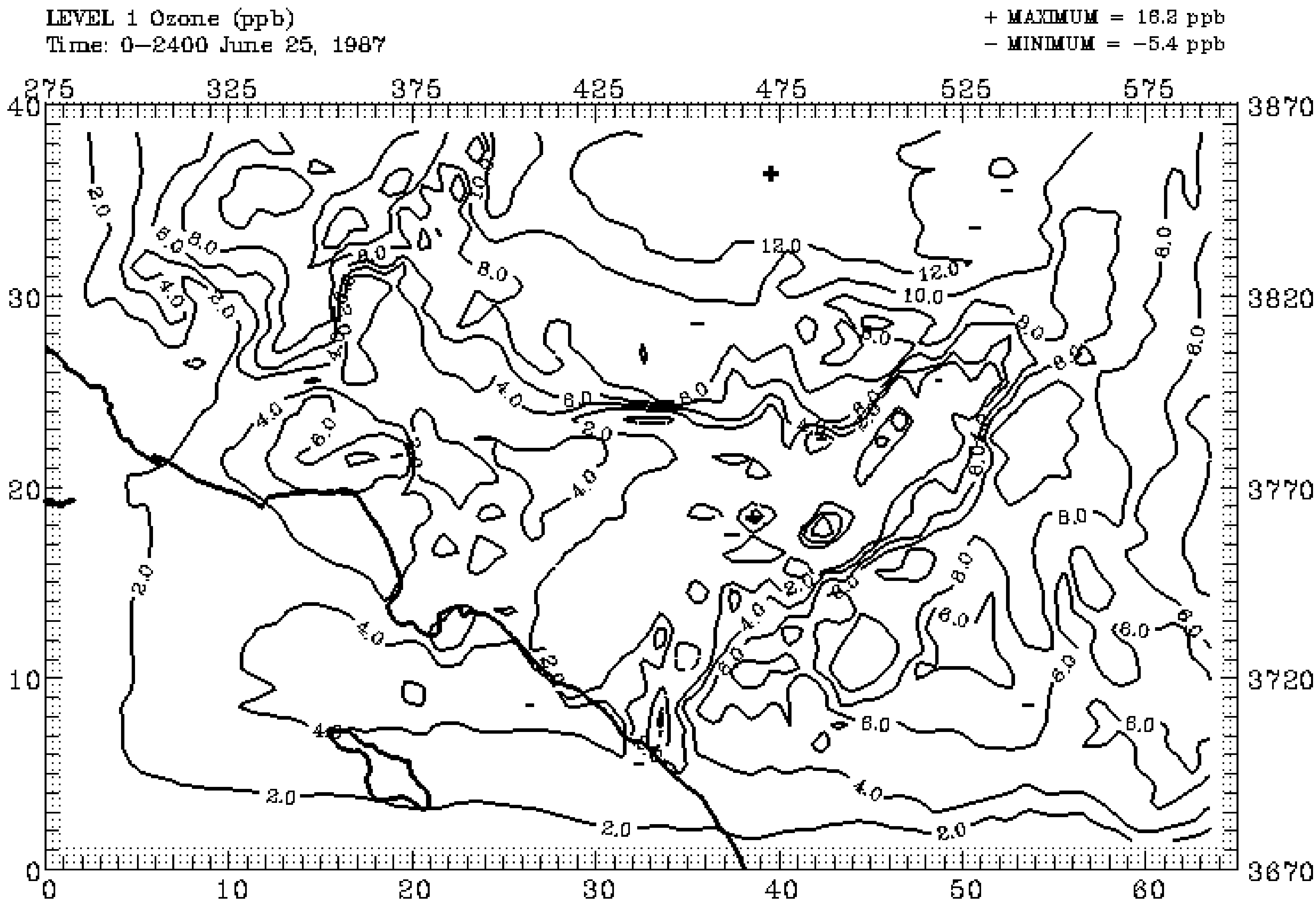


Figure 49c. Difference in maximum simulated ozone concentrations with UAM/FCM between highflux and stdcb4 for base year run - August 28, 1987.

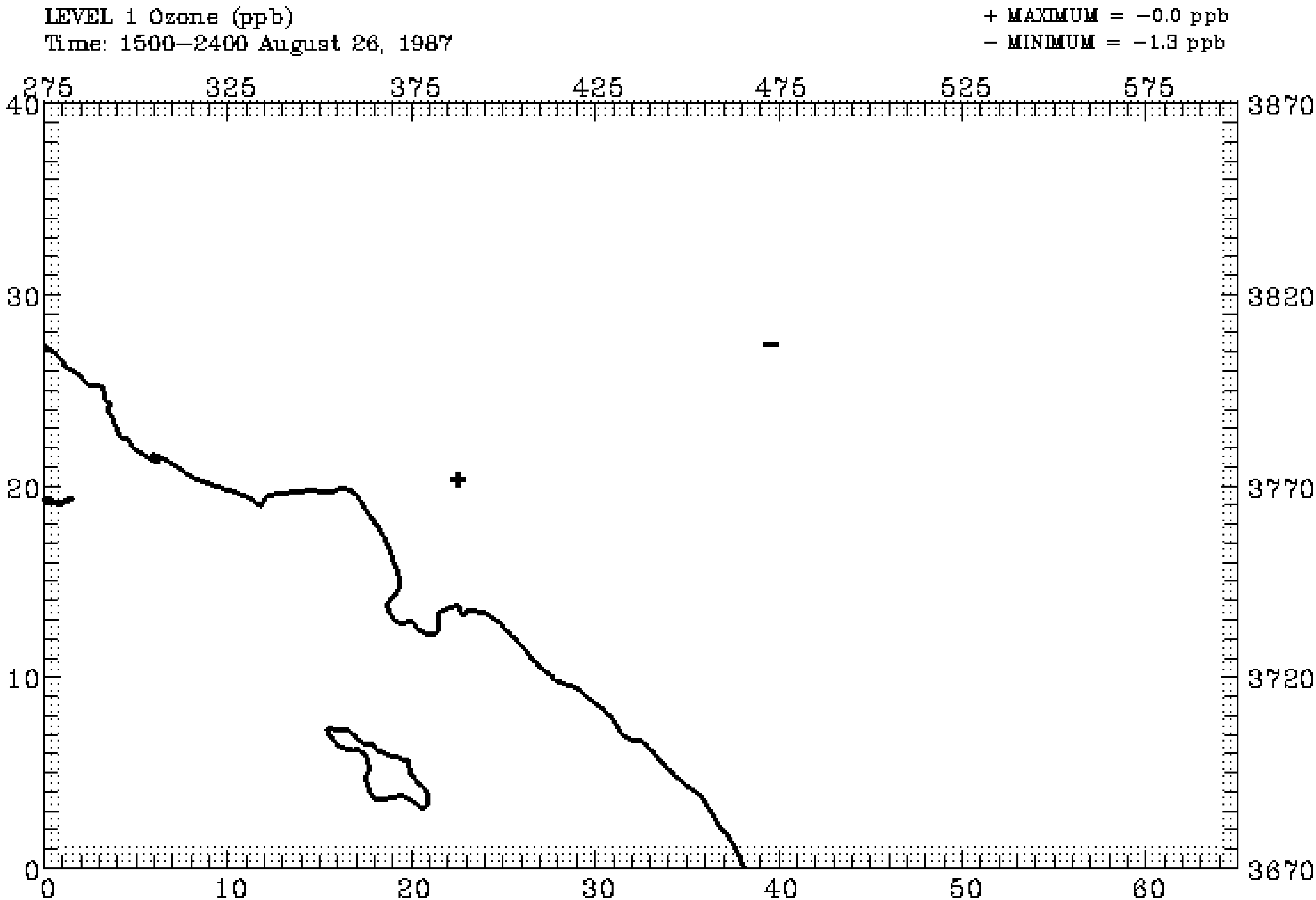


Figure 50a. Difference in maximum simulated ozone concentrations with UAM/FCM between lowflux and stdcb4 for base year run - August 26, 1987.

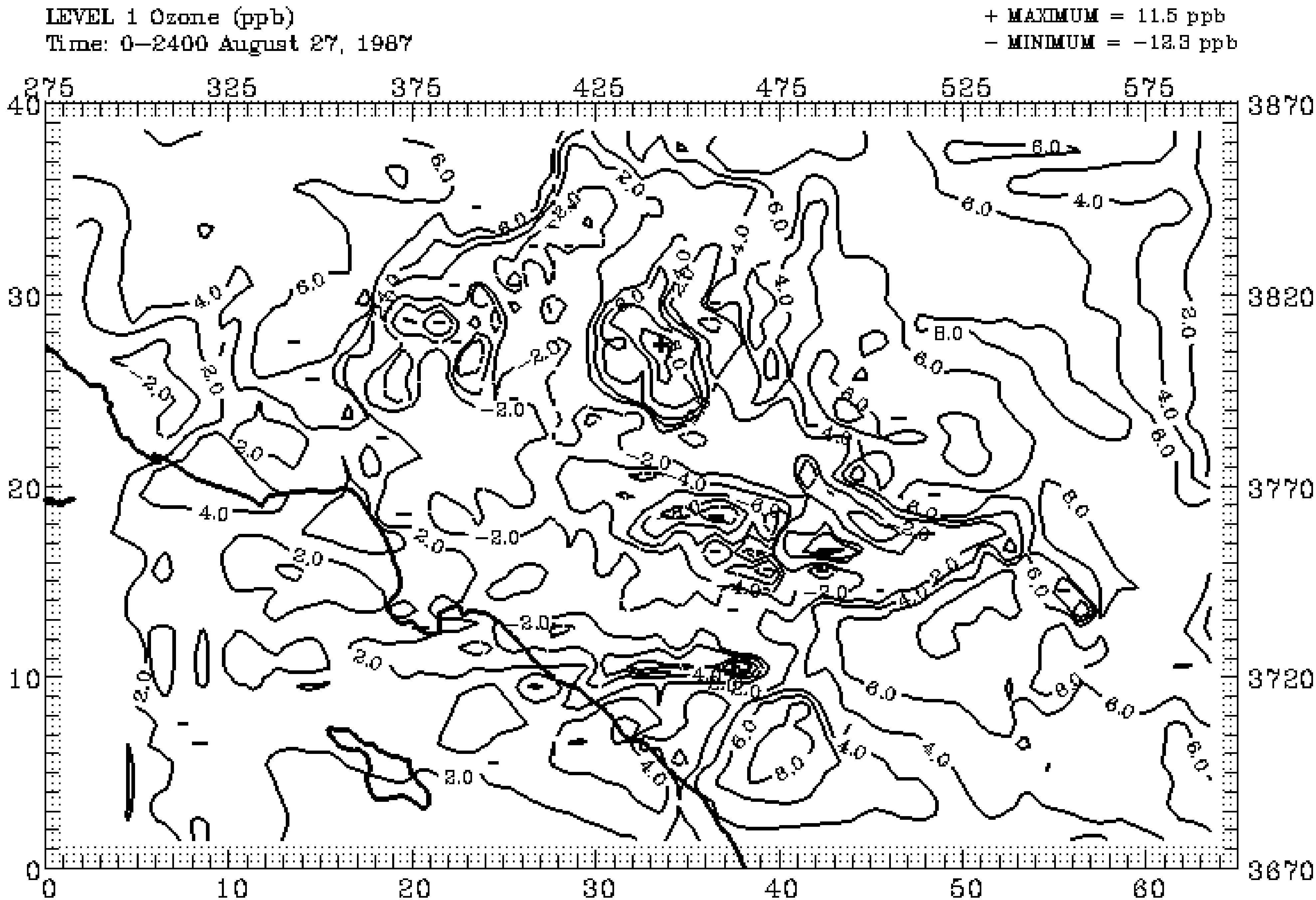


Figure 50b. Difference in maximum simulated ozone concentrations with UAM/FCM between lowflux and stdcb4 for base year run - August 27, 1987.

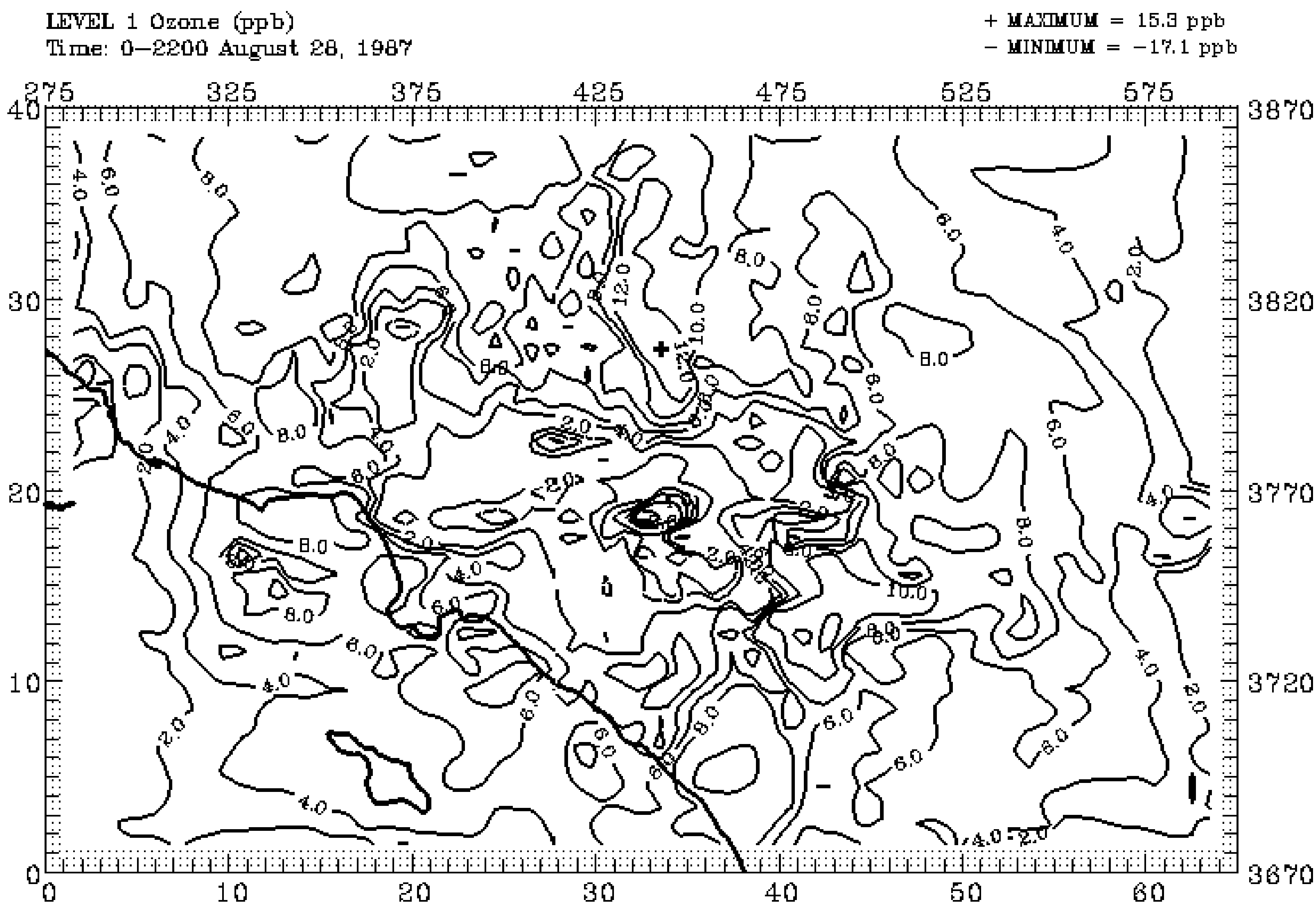


Figure 50c. Difference in maximum simulated ozone concentrations with UAM/FCM between lowflux and stdcb4 for base year run - August 28, 1987.

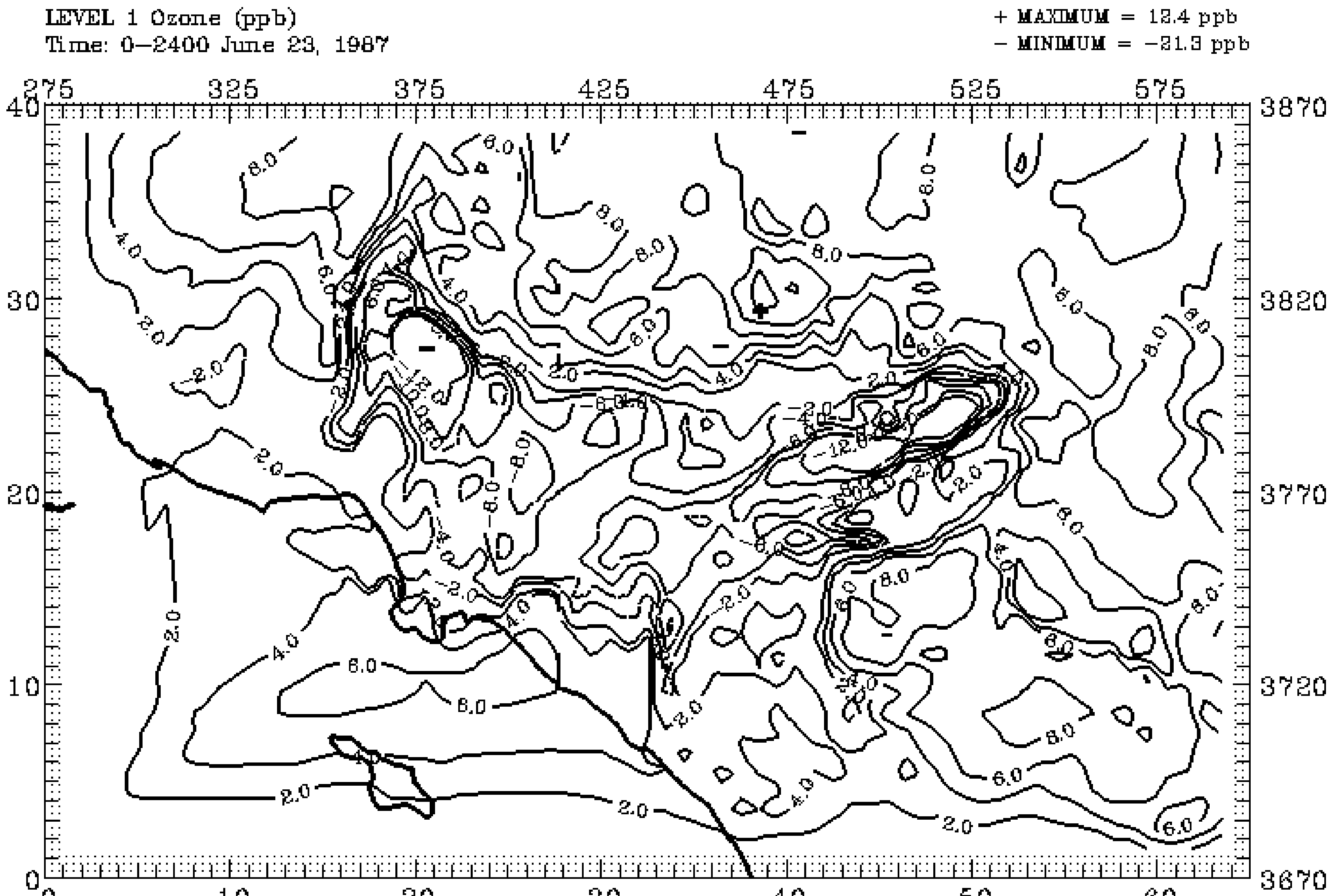


Figure 51a. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for stdcb4 - August 26, 1987.

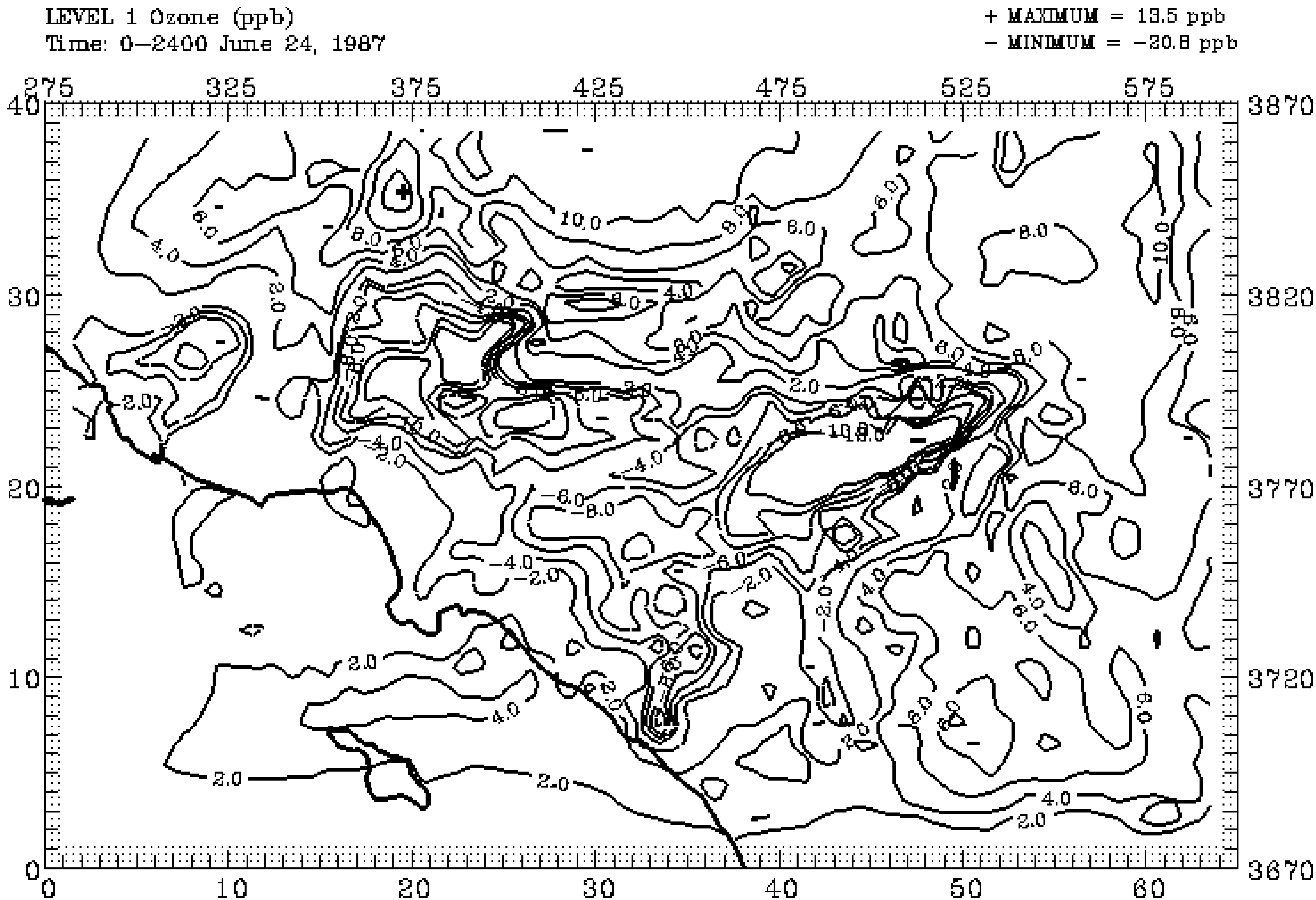


Figure 51b. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for stdcb4 - August 27, 1987.

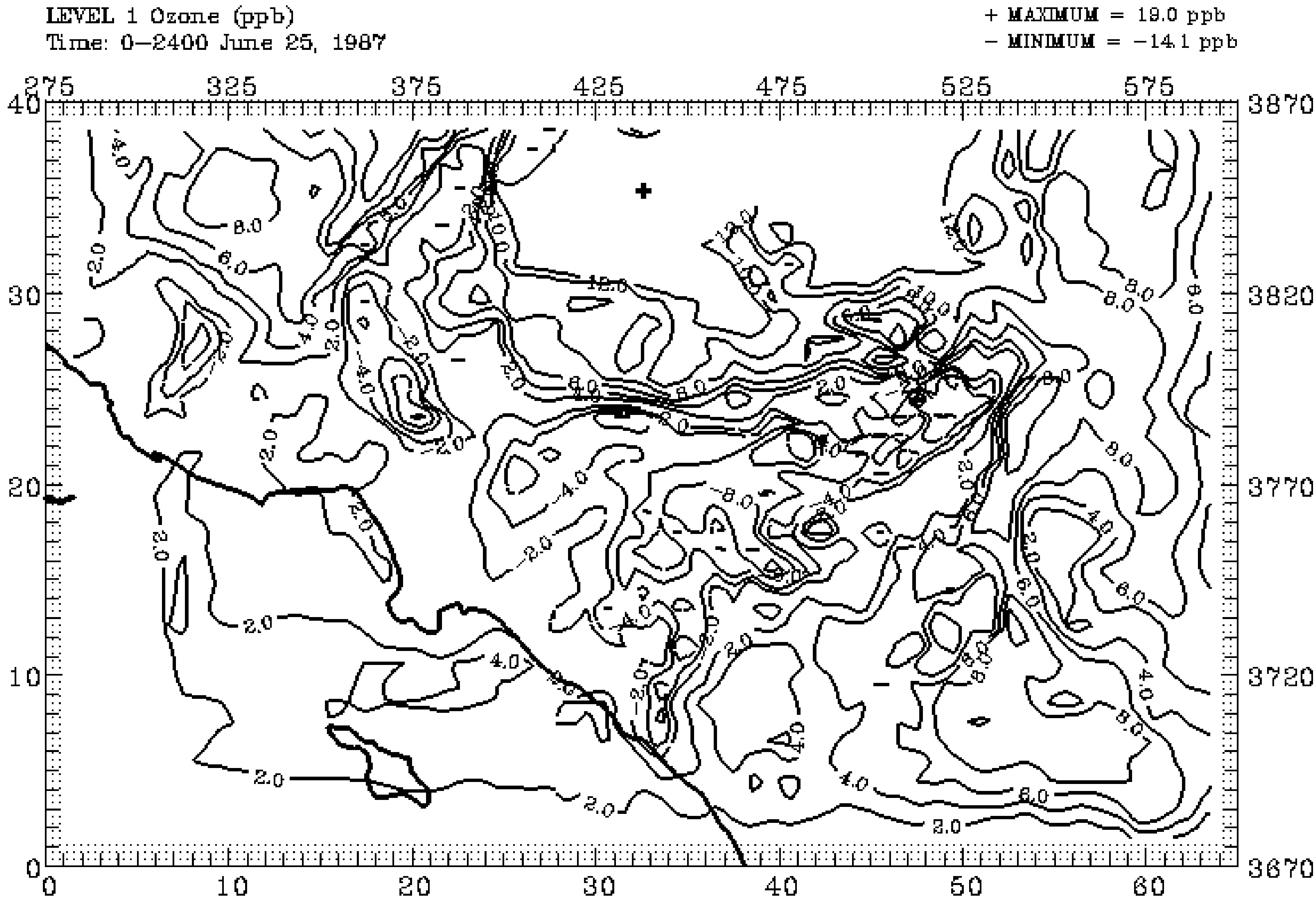


Figure 51c. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for stdcb4 - August 28, 1987.

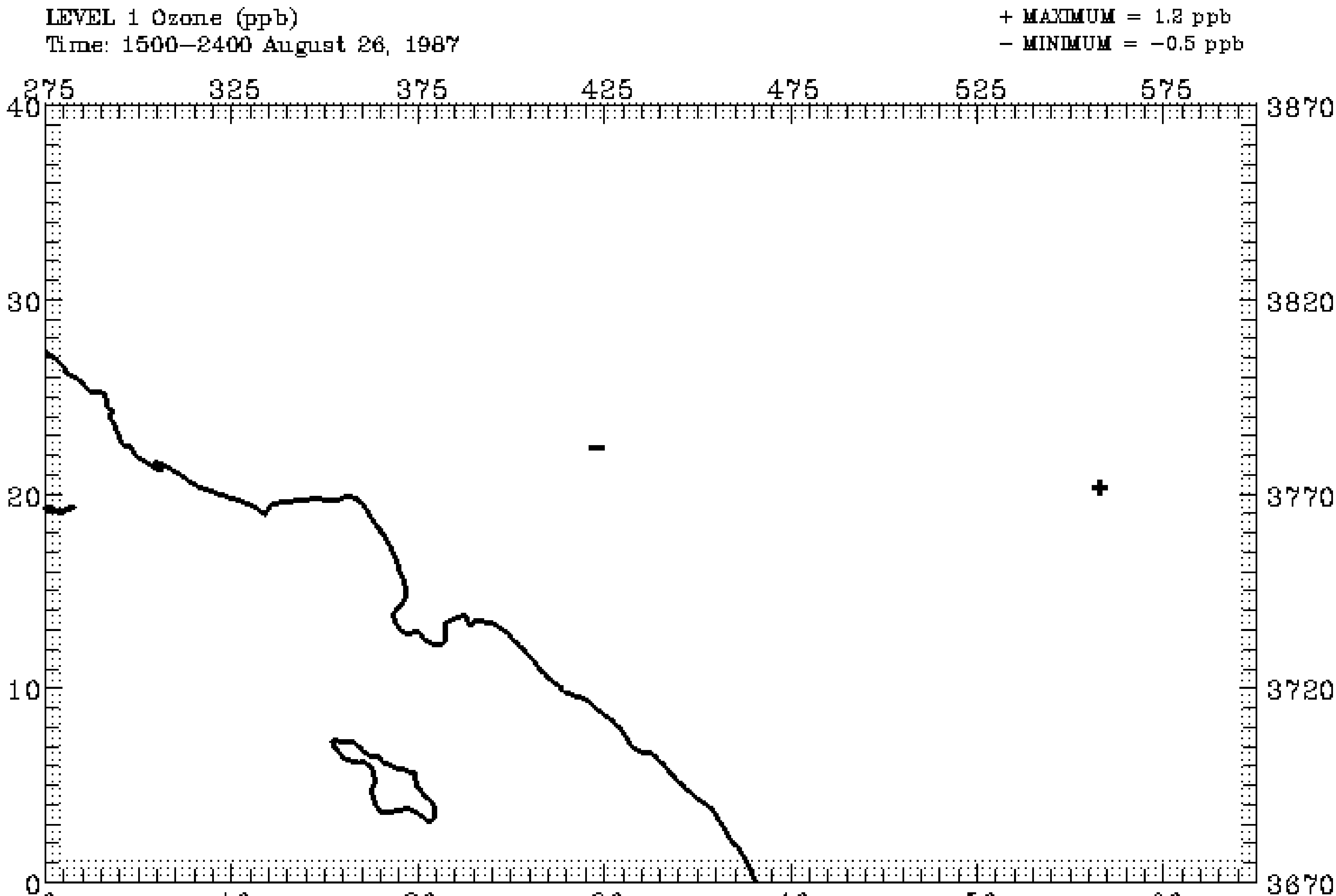


Figure 52a. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for stdcb4 - August 26, 1987.

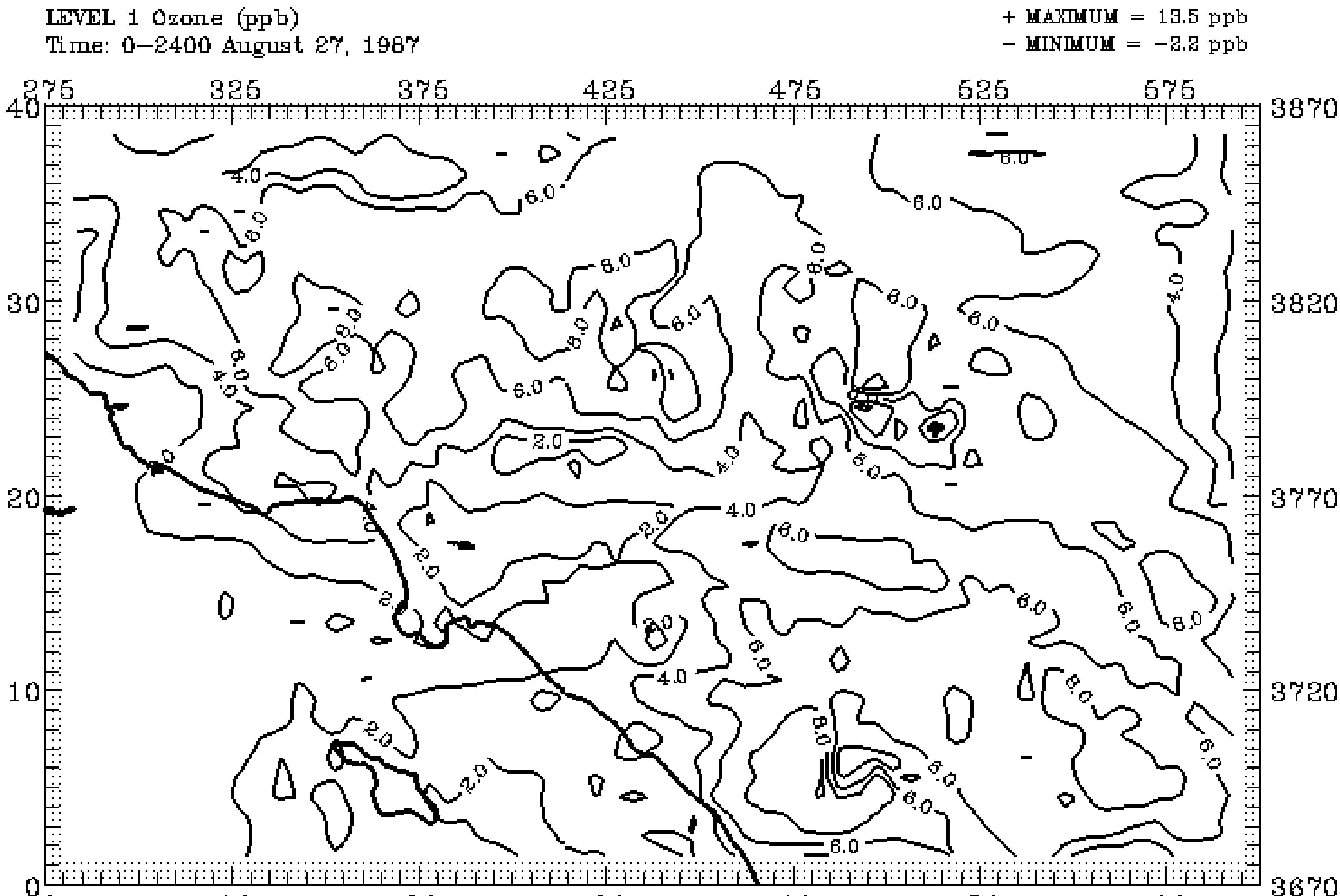


Figure 52b. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for stdcb4 - August 27, 1987.

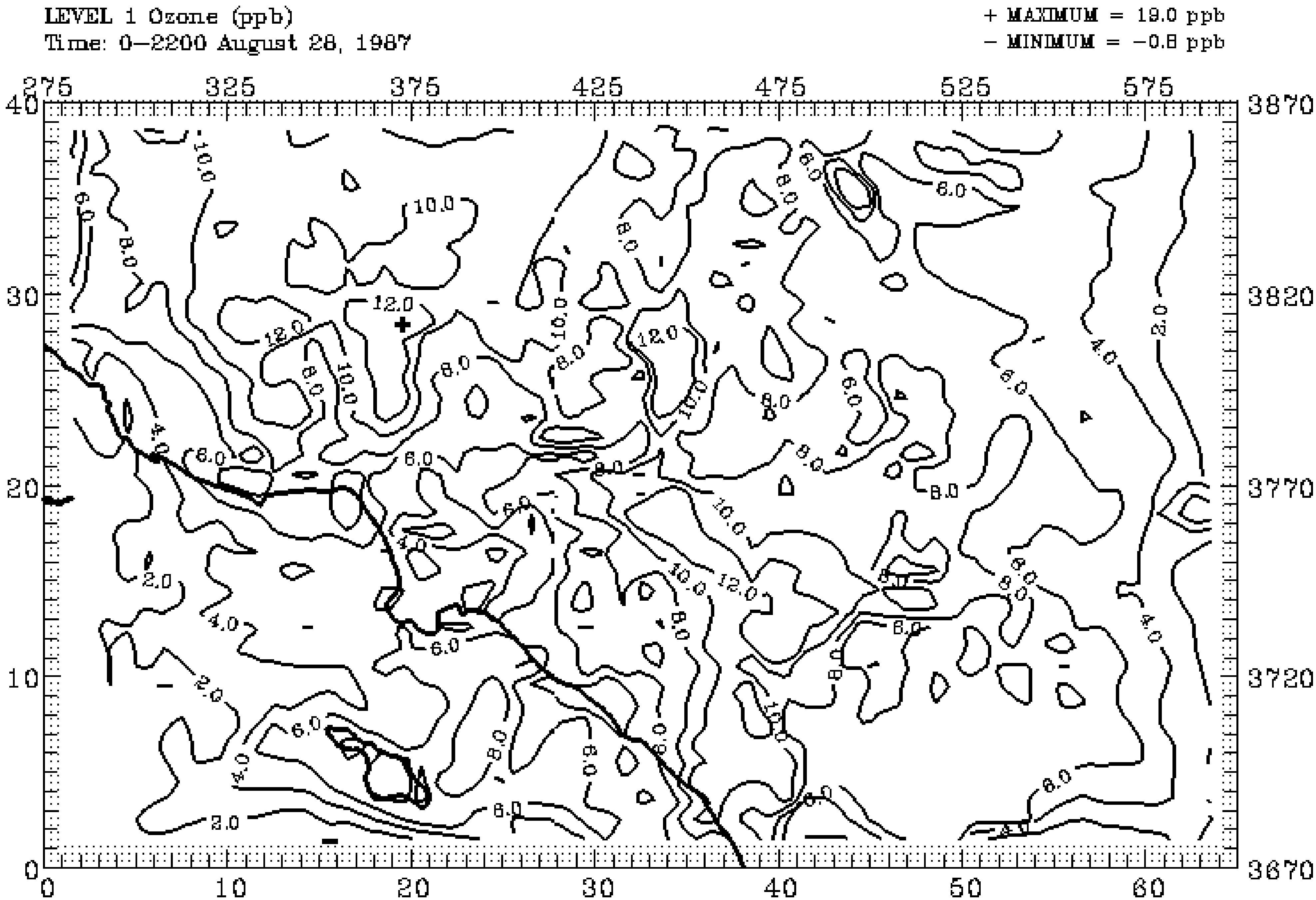


Figure 52c. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for stdcb4 - August 28, 1987.

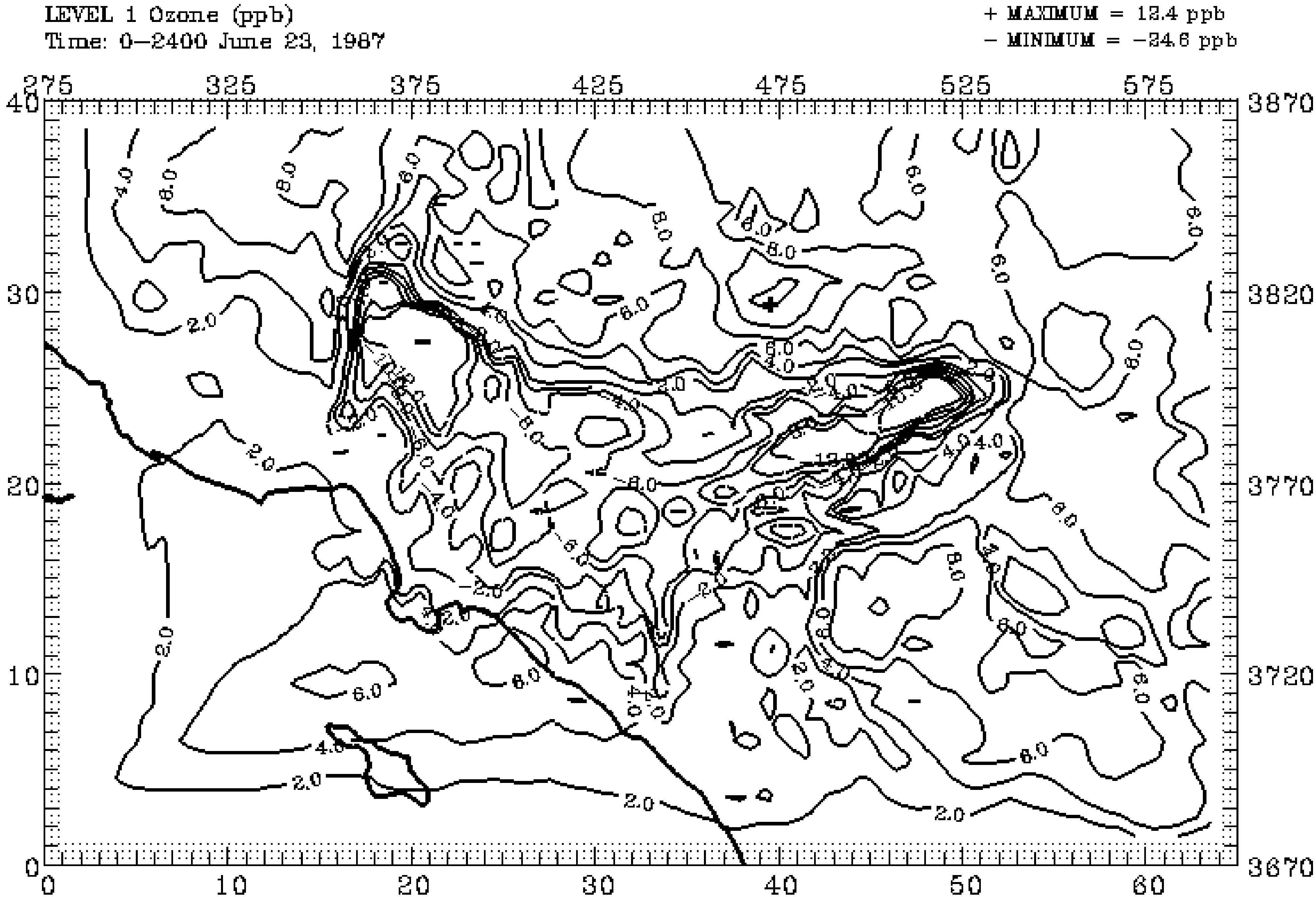


Figure 53a. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for highflux - August 26, 1987.

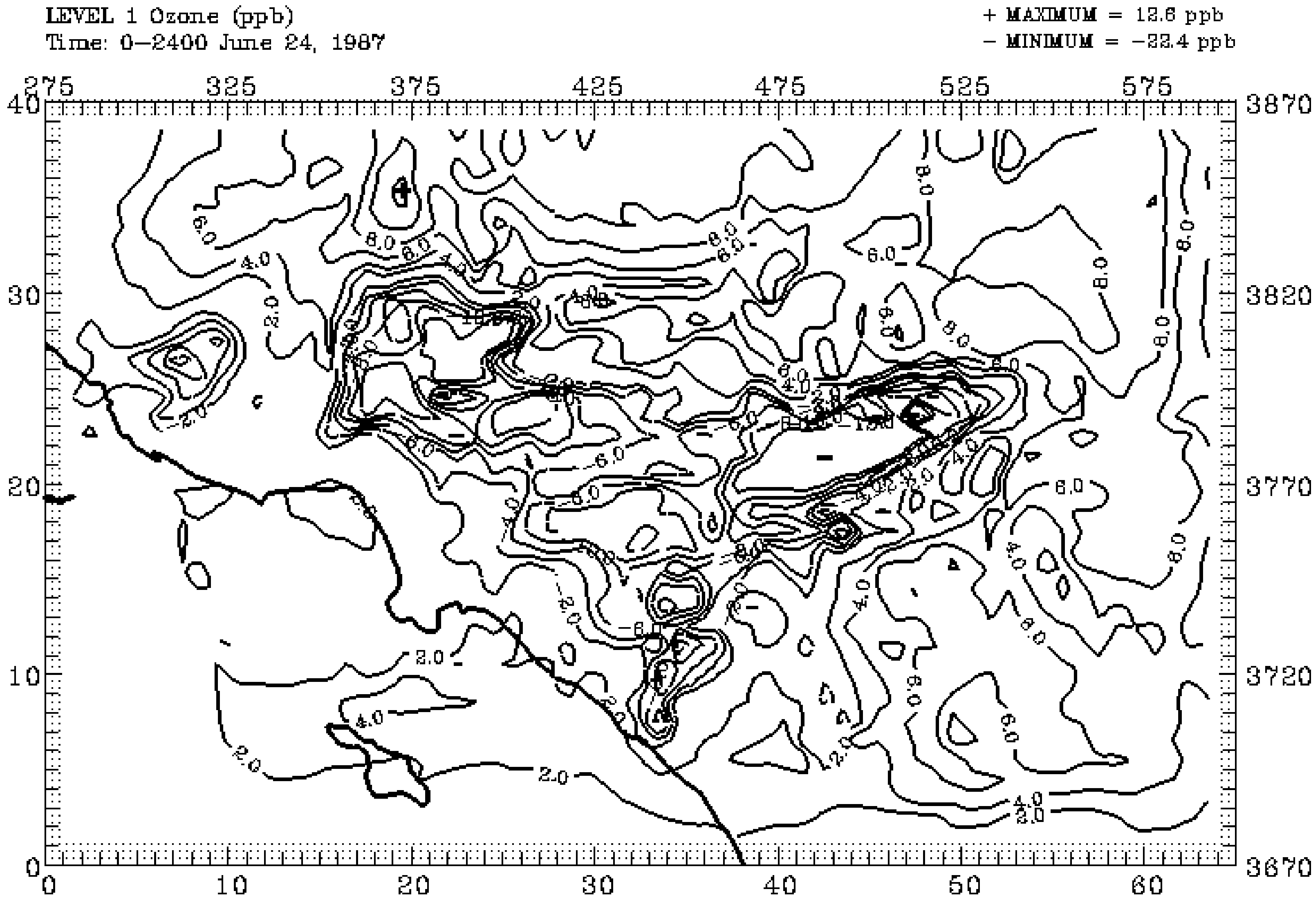


Figure 53b. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for highflux - August 27, 1987.

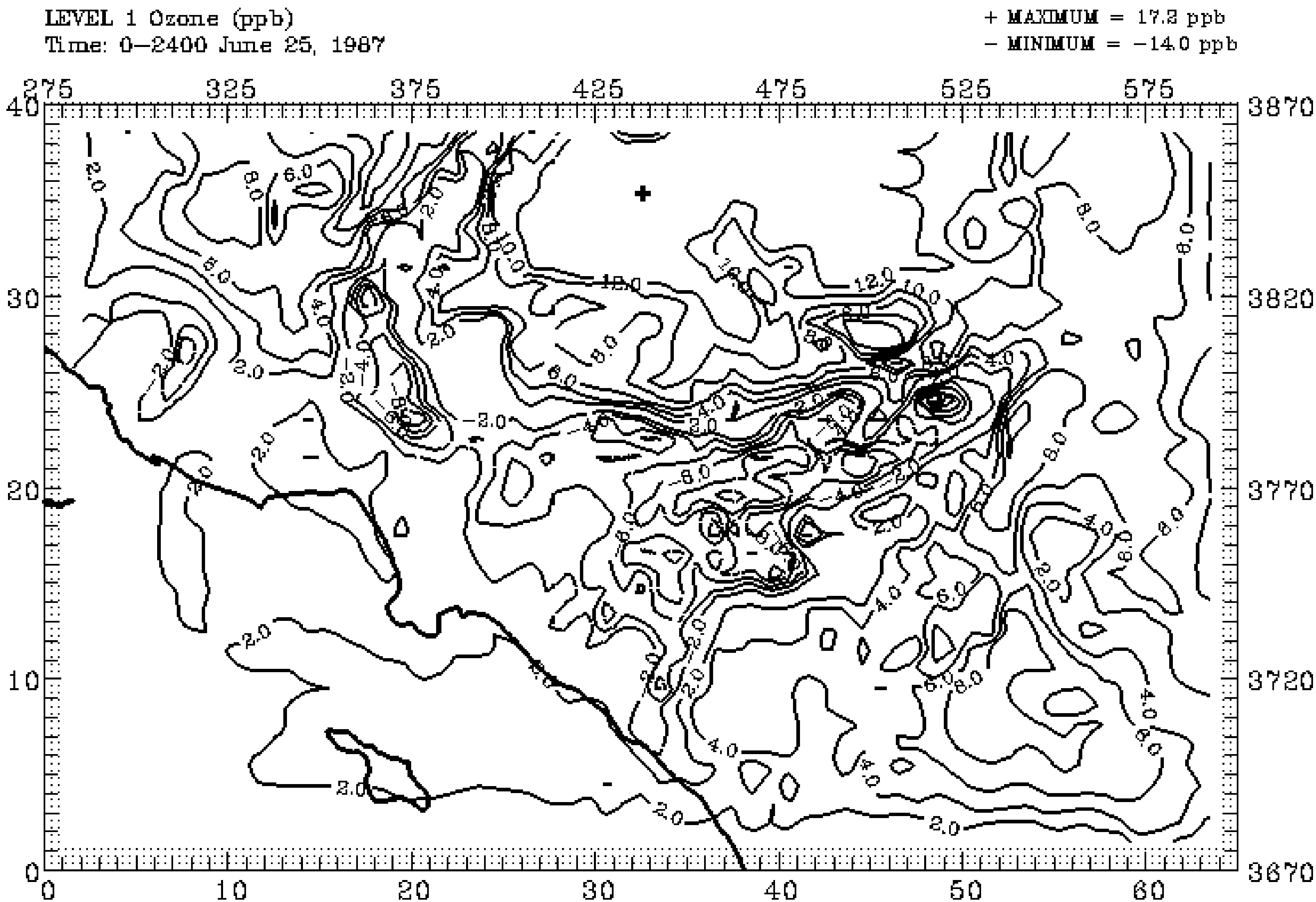


Figure 53c. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for highflux - August 28, 1987.

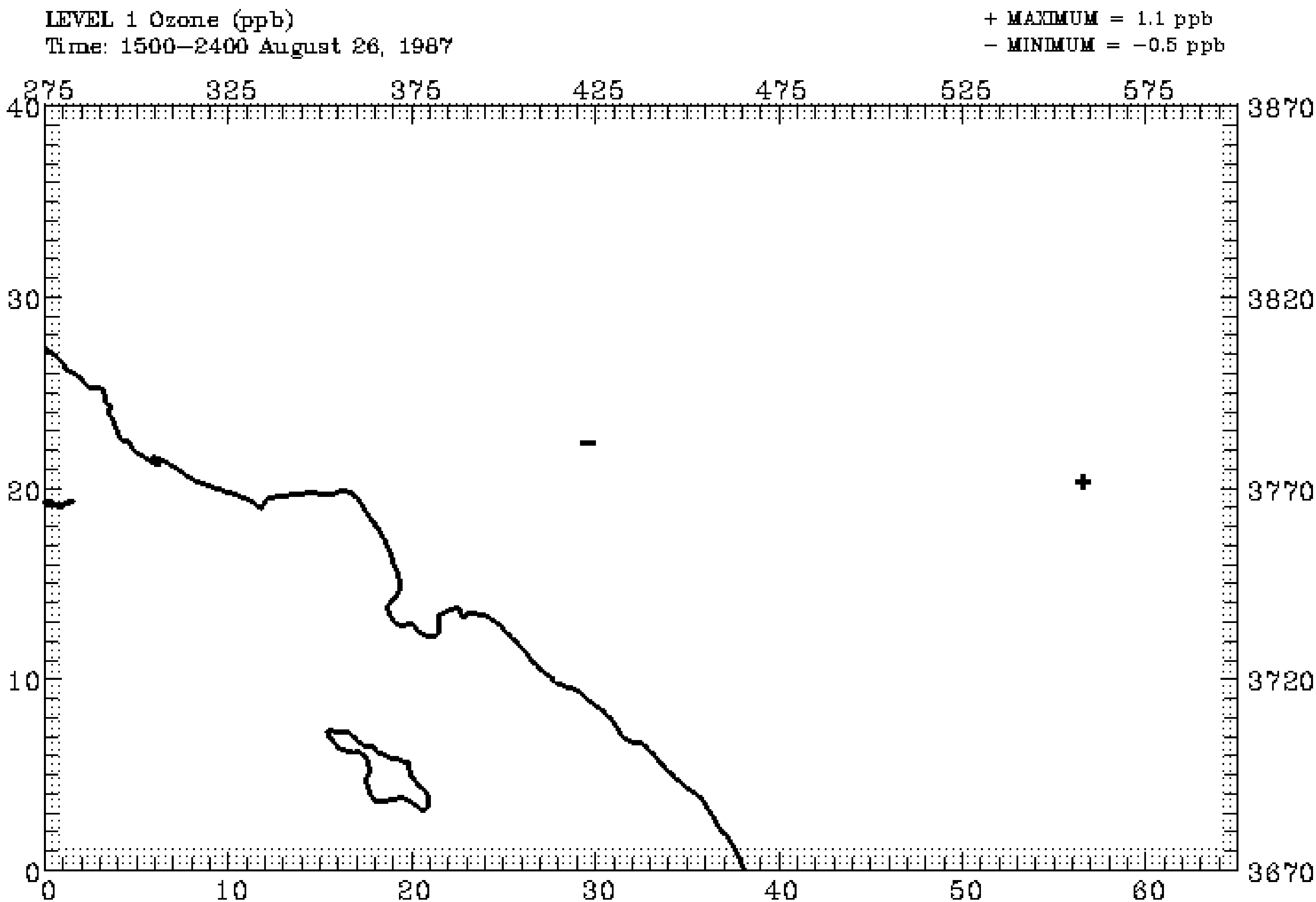


Figure 54a. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for highflux - August 26, 1987.

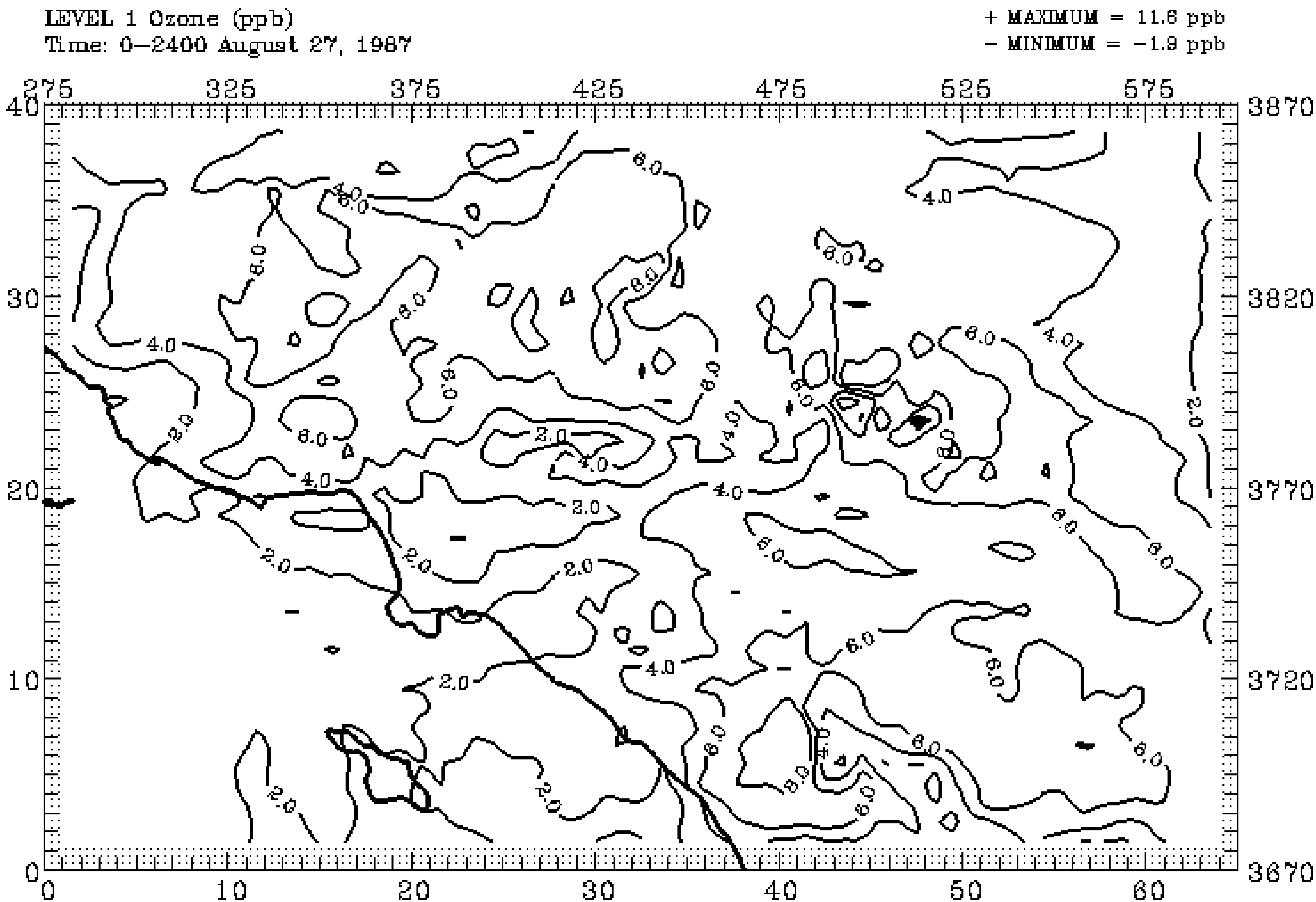


Figure 54b. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for highflux - August 27, 1987.

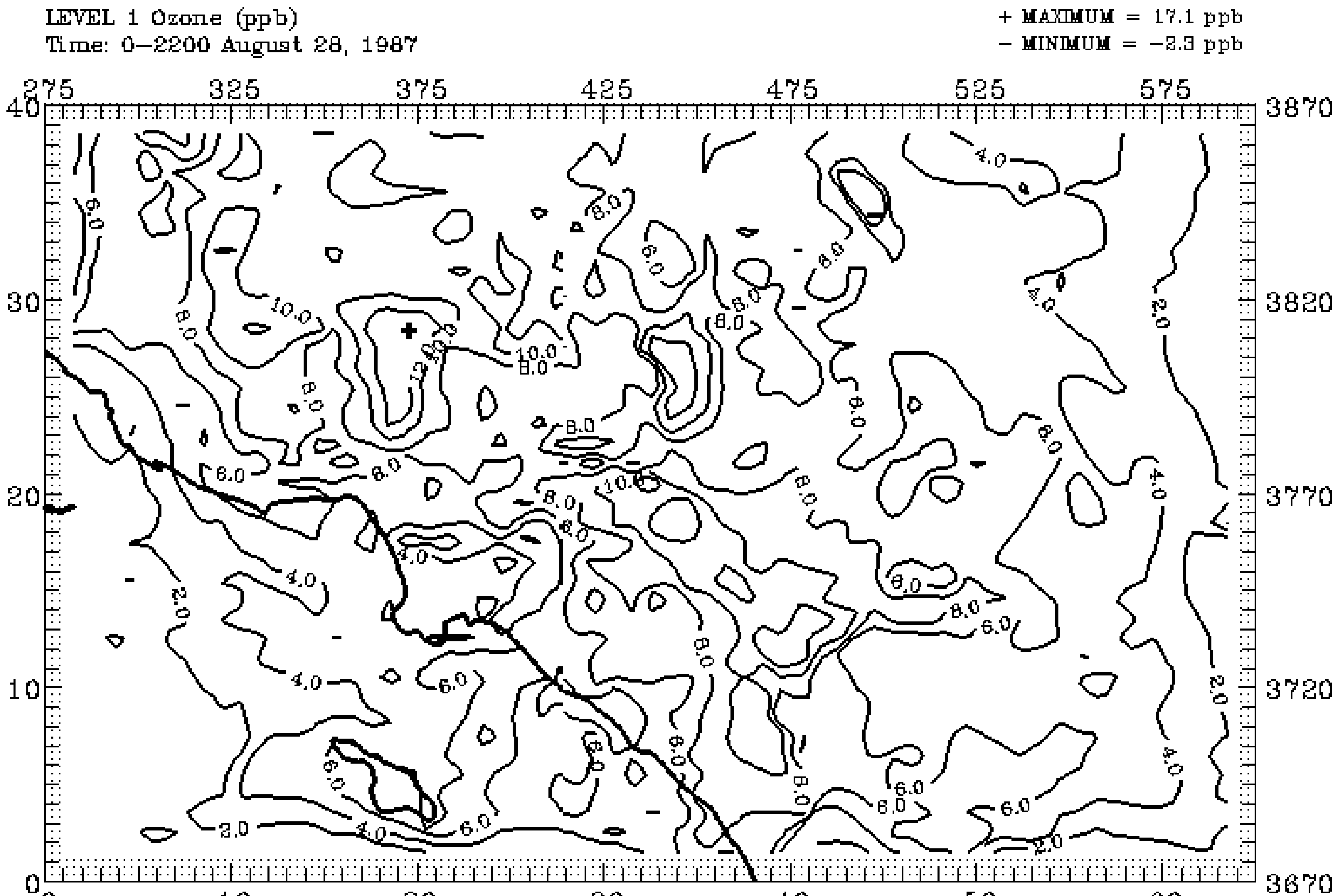


Figure 54c. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for highflux - August 28, 1987.

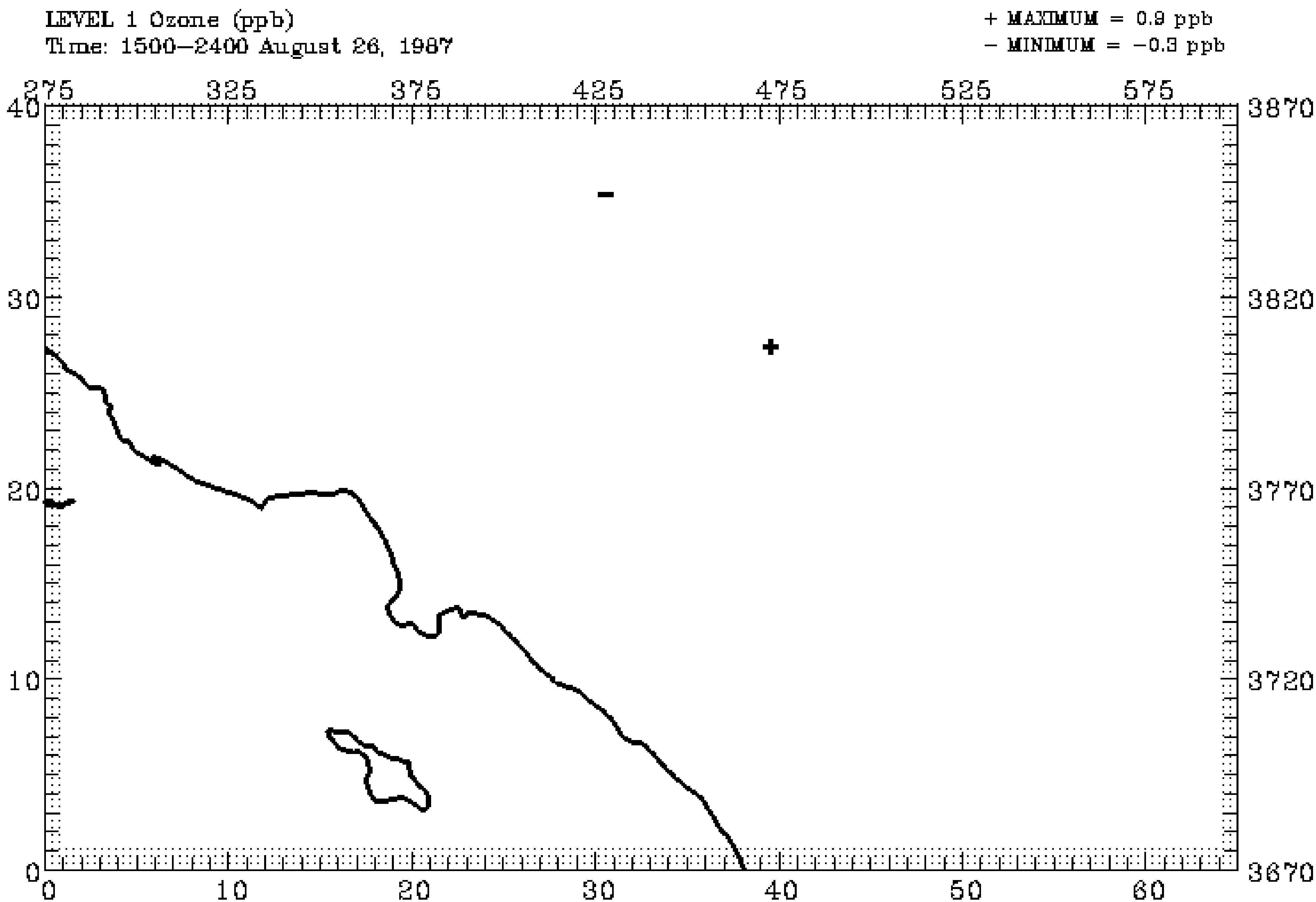


Figure 55a. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for lowflux - August 26, 1987.

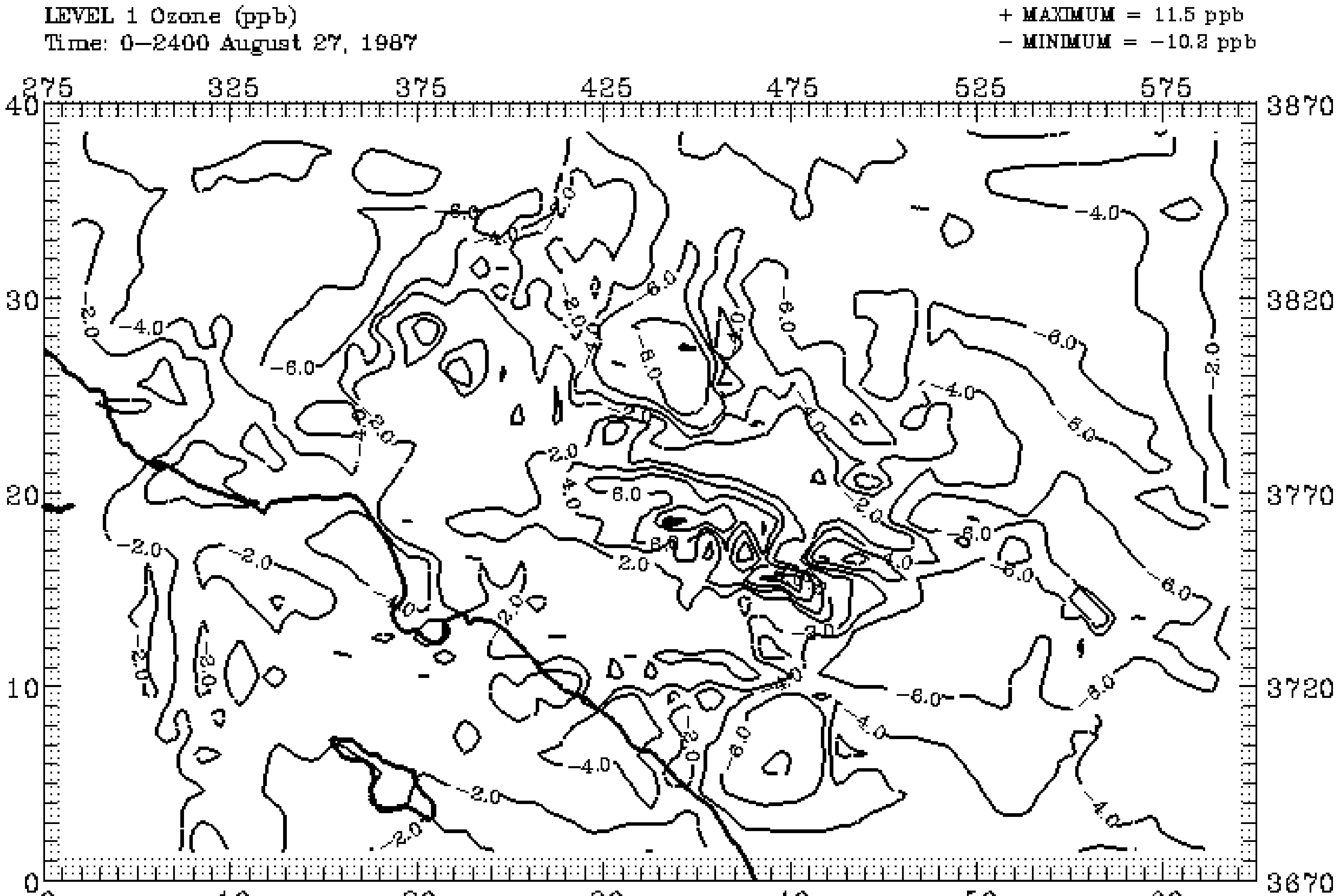


Figure 55b. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for lowflux - August 27, 1987.

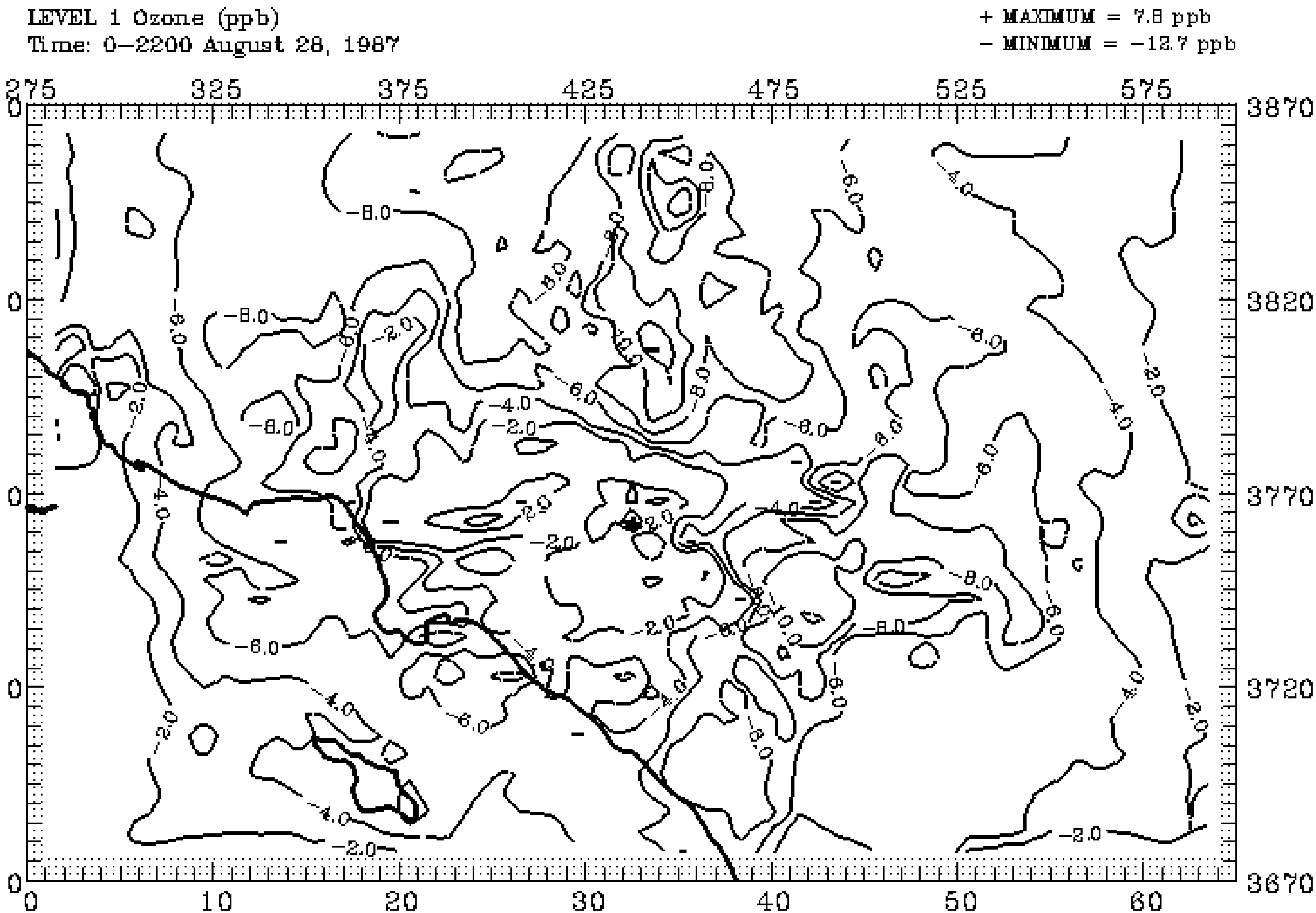


Figure 55c. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for lowflux - August 28, 1987.

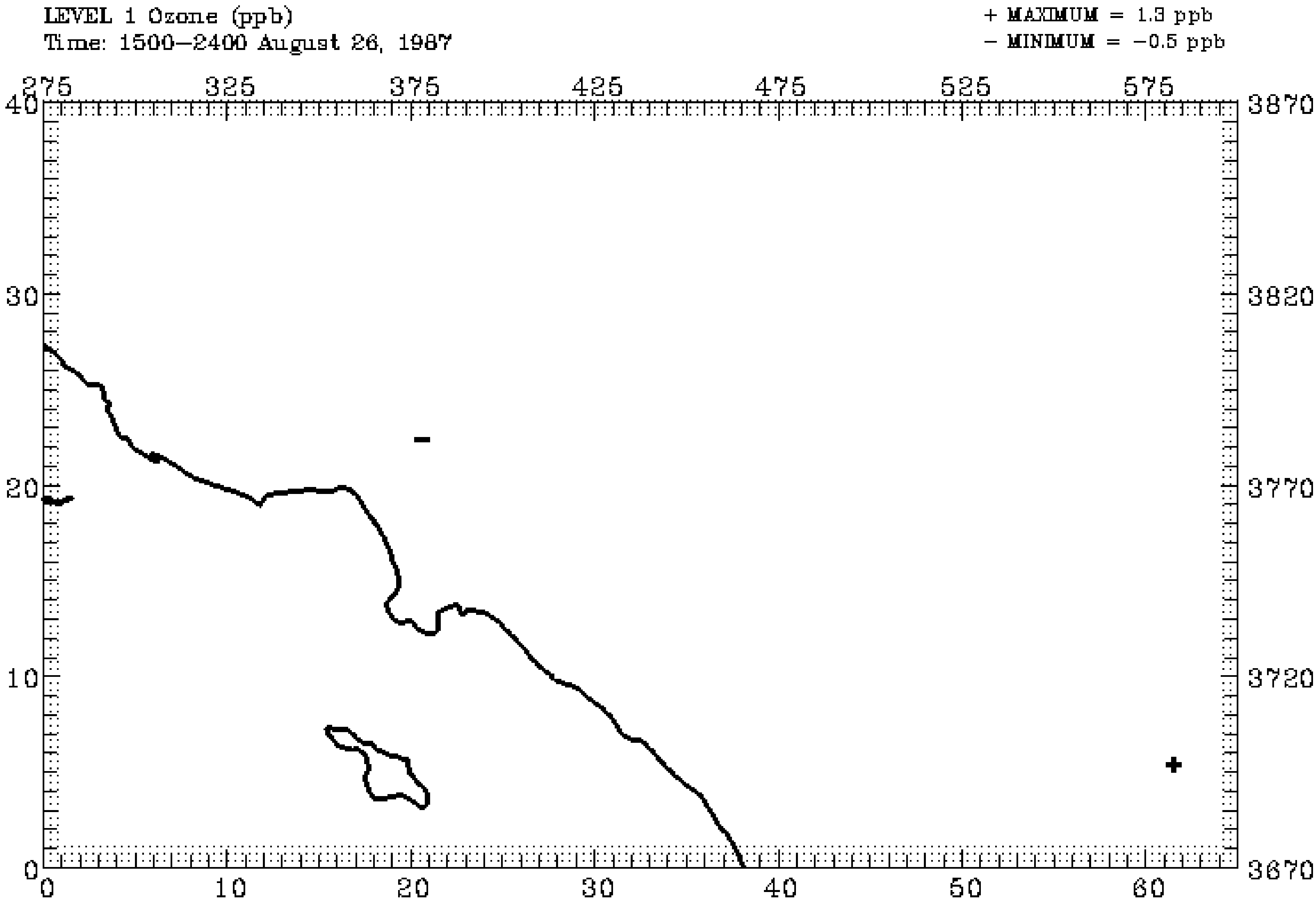


Figure 56a. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for lowflux - August 26, 1987.

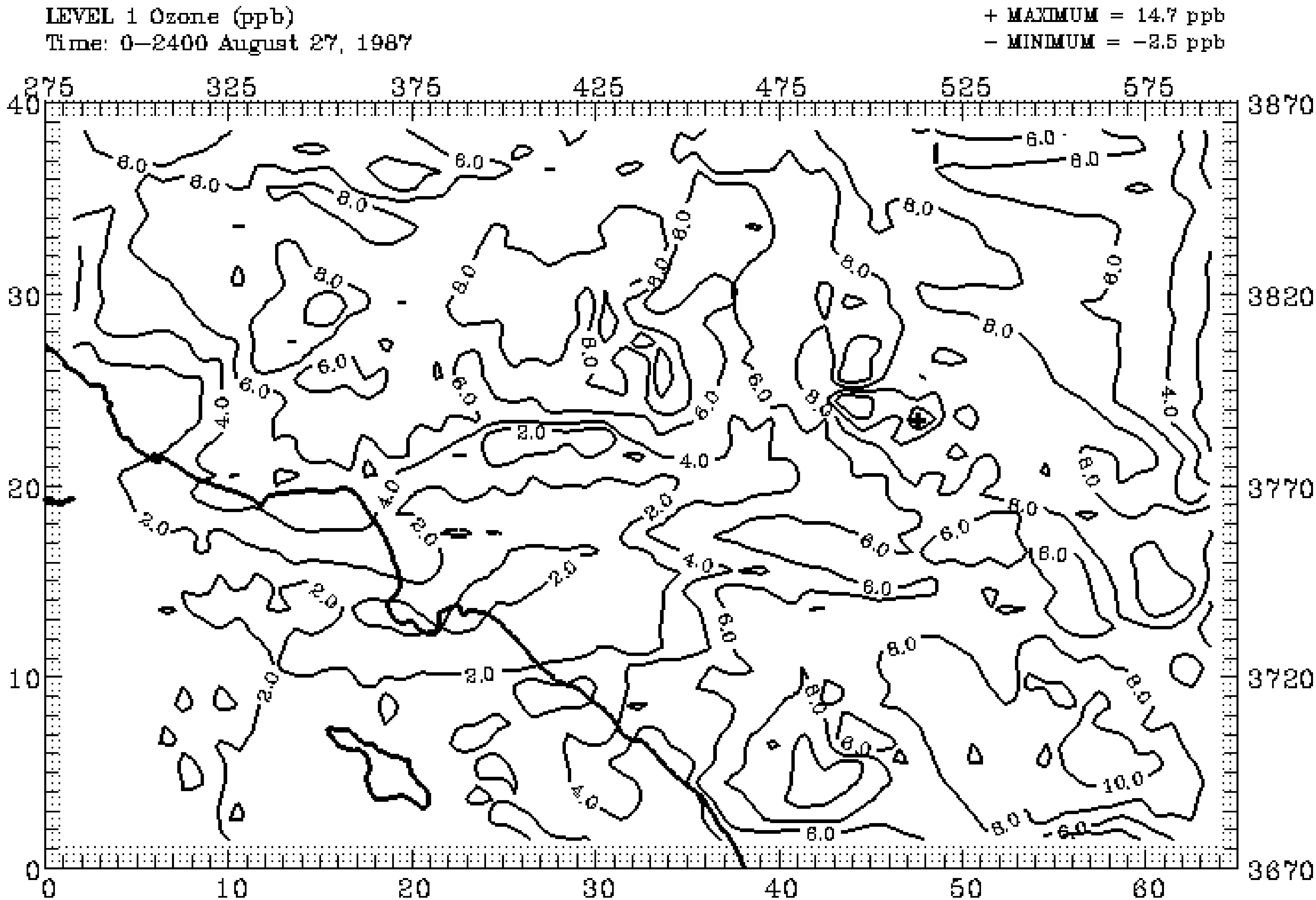


Figure 56b. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for lowflux - August 27, 1987.

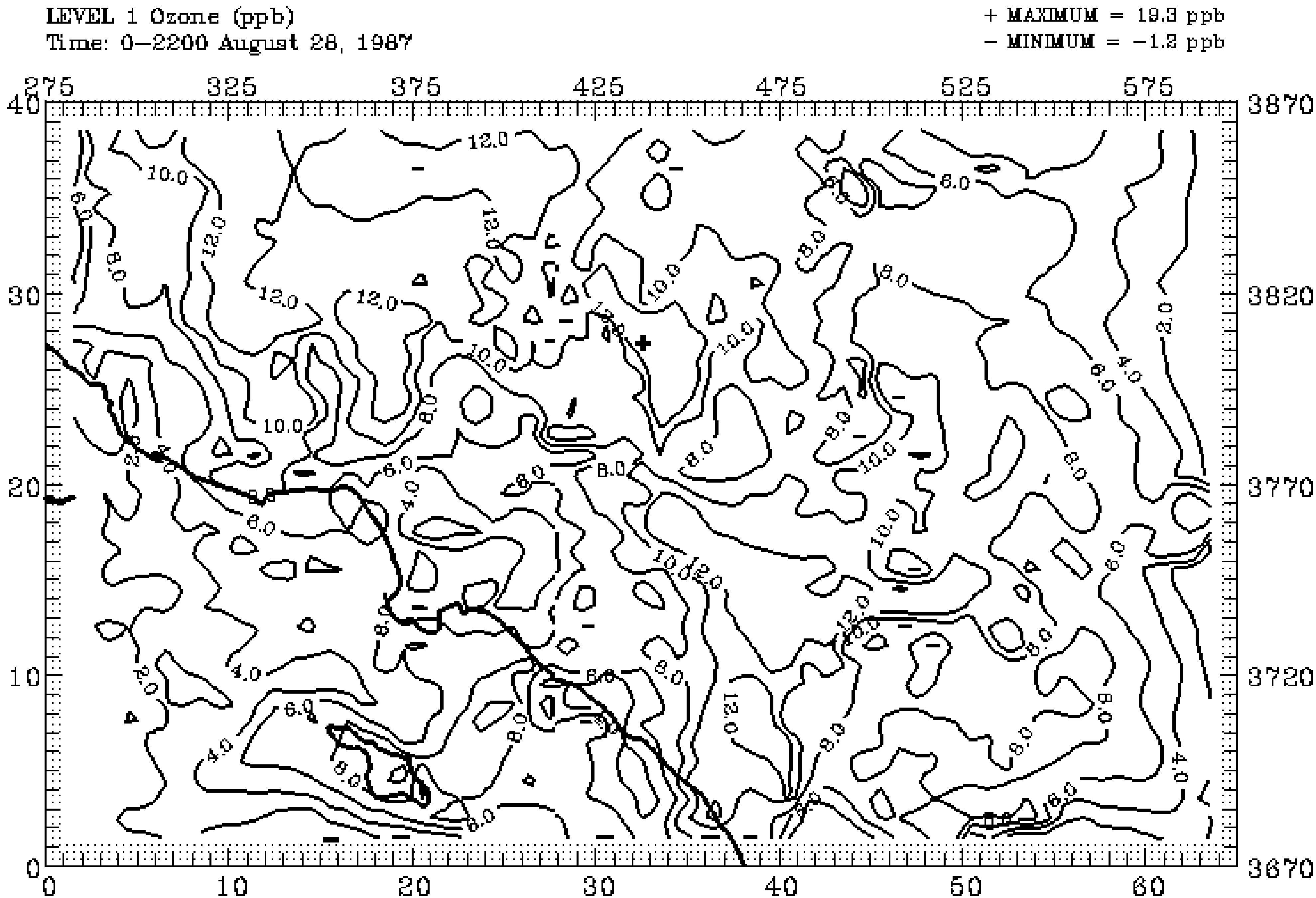
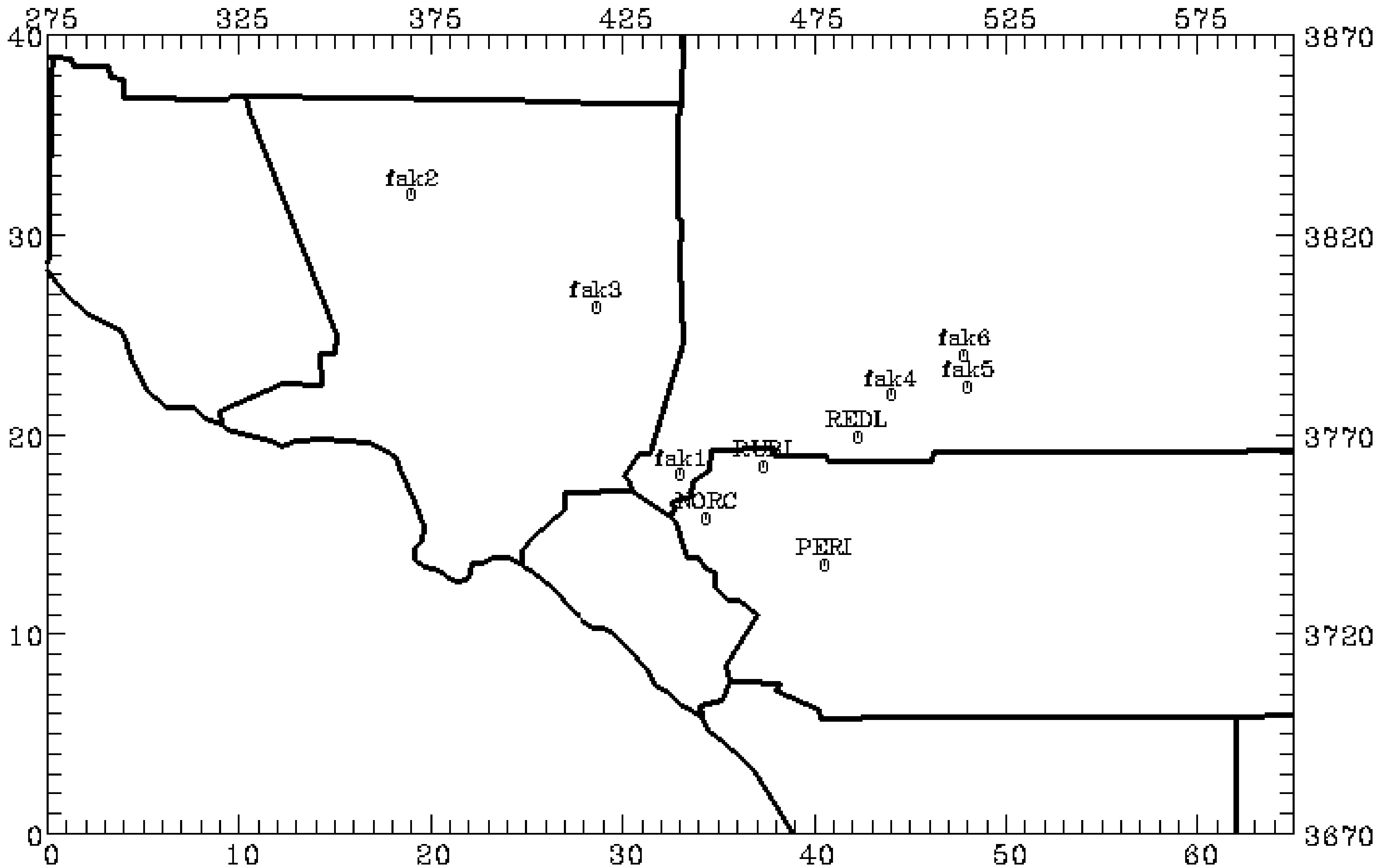


Figure 56c. Difference in maximum simulated ozone concentrations between UAM/FCM and UAM/CB4 for lowflux - August 28, 1987.



South Coast Air Basin

Fake stations

Figure 57. Location of "Fake" stations referenced in Tables 5 and 6.